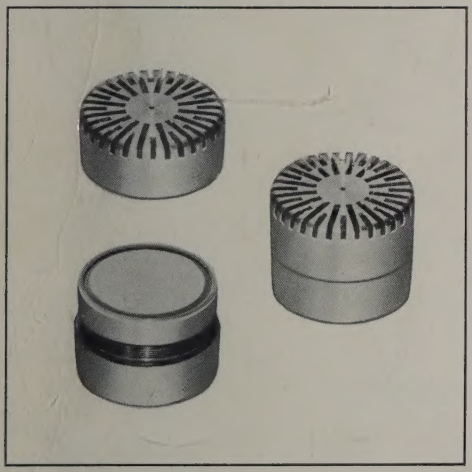
4144, 4145, 4146

Instructions and Applications



Condenser Microphones
Types 4144, 4145, 4146

High stability precision condenser microphones for measurement purposes, with the possibility of low frequency measurements down to 0.1 Hz. Each microphone is individually calibrated.

BRÜEL & KJÆR

030-0161

CONDENSER MICROPHONES 4144/45/46

April 1970

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1. INTRODUCTION

1.1. GENERAL

The condenser microphone's operating characteristics of high stability, flat linear response, and reasonably high sensitivity, combined with its minimal effect on the sound fields in which it is placed, make it for most purposes, the most suitable transducer available for measuring sound pressures.

The B & K 1" Condenser Microphone Types 4144, 4145 and 4146 are developments of the previous 4131 and 4132 types which are accepted as measuring microphones and laboratory standards of the highest quality. Their appearance and construction are basically similar to the earlier types but the experience gained in manufacture has culminated in significant design modifications and revised production techniques. These have resulted in considerable improvements in long term stability, higher leakage resistance and closer tolerances in operating characteristics. They are designed for use with a range of instruments: microphone amplifiers, frequency analyzers, precision sound level meters etc., to give a complete analysis of the sound fields measured.

The 4144 has an output proportional to the sound pressure acting on the diaphragm and a frequency range extending from 1.5 Hz ± 0.5 Hz (−3 dB) to 7.5 kHz (± 1.5 dB). The 4145 has a response which is corrected for free field measurements giving a linear output from 1.5 Hz ± 0.5 Hz (−3 dB) to 18 kHz (± 1.5 dB).

The 4146 is identical in construction to the 4144 but the low frequency range has been extended downwards to below 0.1 Hz (−3 dB). An adapter kit is available to extend the lower limiting frequency of the 4144 (and 4145) down to about 0.1 Hz.

The microphones meet the requirements of the American National Standards Institute for laboratory standard Type L microphones, 4145 for free field use and 4144, 4146 for pressure measurements. They are of rugged construction and are suitable for field use but are not designed for permanent exposure outside unless special precautions are taken.

1.2. PRINCIPLE OF CONDENSER MICROPHONE

A condenser microphone consists essentially of a thin metallic diaphragm mounted in close proximity to a rigid back plate, both being electrically insulated and forming the electrodes of a capacitor (Fig.1.1). A stabilized DC polarization voltage maintains a constant charge between the electrodes, provided the time constant of the charging circuit is much longer than the period of the sound pressure variations. When sound pressure waves are incident on the diaphragm, the capacitance changes and an E.M.F. is produced. By careful design, the output voltage is made proportional to the sound pressure level through extended frequency and dynamic ranges.

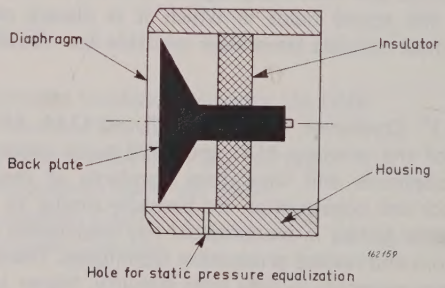


Fig.1.1 Diagram of a Condenser Microphone

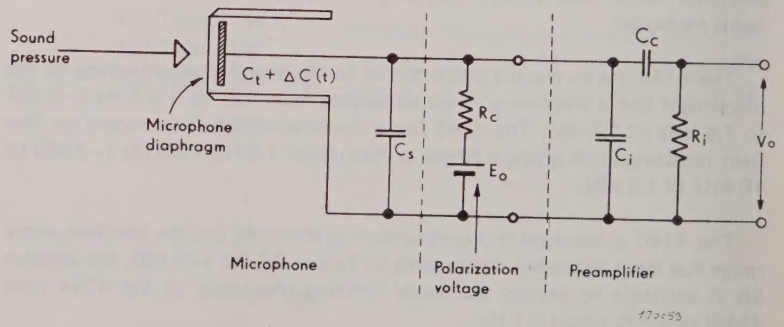


Fig.1.2 Simplified Circuit Diagram of Condenser Microphone and Preamplifier

A condenser microphone is a small capacitance and requires a preamplifier of special design. A simplified circuit diagram of a condenser microphone and preamplifier is shown in Fig.1.2 and its equivalent circuit in Fig.1.3. It can be seen that the output voltage is

$$V_o = \frac{\Delta C\,(t)}{C_t} \cdot E_o \cdot \frac{j\,\omega\,R\,C}{1 + j\,\omega\,R\,C}$$

where E_o = polarization voltage
C_t = capacitance of transducer (microphone cartridge)
$\Delta C\,(t)$ = variation in capacitance due to sound pressure
C_s = stray capacitance
C_c = coupling capacitance
C_i = input capacitance of preamplifier
$C = C_t + C_s + C_i$
R_c = charging resistance
R_i = input resistance of preamplifier

$$R = \frac{R_i\,R_c}{R_i + R_c}$$

$C_c >>$ C and is therefore neglected in the equivalent circuit

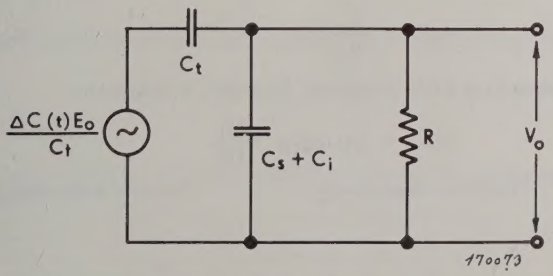


Fig. 1.3 Equivalent Circuit of Condenser Microphone and Preamplifier

It is seen that the sensitivity is proportional to the polarization voltage but inversely proportional to the total capacitance C. Any capacitance additional to the transducer capacitance e.g. that of the preamplifier would load the transducer and decrease the output voltage V_o. This means that the total capacitance in the circuit should not exceed the capacitance of the transducer more than necessary. Hence the need for integral construction of the cartridge and preamplifier.

1.3. DEFINITION OF FREE-FIELD, PRESSURE AND DIFFUSE FIELD RESPONSE

The sensitivity of a transducer is normally expressed as the ratio of its electrical output to its acoustic input and is, in general, a function of frequency, being constant in a broad frequency range. When the sound pressure is applied uniformly over the surface of the diaphragm, the ratio of the RMS output voltage, e, to the RMS sound pressure, P_1, is called the pressure response, M_p, of a microphone at a given single frequency and written as

$$M_p = \frac{e}{P_1}$$

The relative pressure response level, R_p in dB, of a microphone is defined with respect to a reference response, M_r, which is equal to

$$1\frac{Vm^2}{N} \text{ or } 1\frac{V}{\mu bar} \text{ or } 1\frac{Vcm^2}{dyne} \text{ thus}$$

$$R_p = 20 \log_{10} \frac{M_p}{M_r}$$

The Free Field Response, M_f, at a given frequency is defined as the ratio of RMS output voltage, e, to RMS sound pressure, P_o, existing before the microphone is placed in the field so

$$M_f = \frac{e}{P_o}$$

The relative Free Field Response, R_f in dB, is defined as

$$R_f = 20 \log_{10} \frac{M_f}{M_r}$$

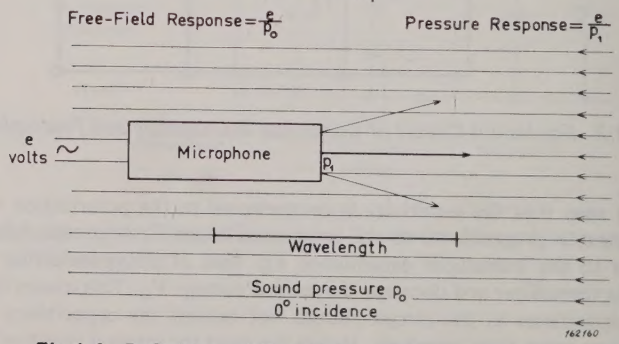


Fig. 1.4 Definition of Free-field and Pressure Response

The definition of Free Field and Pressure Response are illustrated in Fig.1.4. The two definitions are identical for a microphone having negligible dimensions compared to the sound wavelength. If the wavelength becomes comparable to microphone dimensions, the transducer acts as a reflector in the sound field producing a local change in the sound pressure. This causes an increase in pressure on the diaphragm which results in an increase in the output voltage. The reflection effect depends on the angle of incidence of the sound.

The free field response of a microphone is of interest when the transducer is operated in an open space, many wavelengths removed from a sound source or reflecting boundaries.

The pressure response is important in closed cavities, couplers, artificial ears, etc.

If the sound energy density is uniform and the time average of the mean square sound pressure is the same in all directions, the sound field is termed a Diffuse Field. The ratio of the RMS output voltage, e, to the RMS diffuse field sound pressure, P_d, for all angles of incidence of the sound wave is called the Diffuse Field Response at a given single frequency and is defined as

$$M_d = \frac{e}{P_d}$$

The relative Diffuse-field response level, R_d in dB, is defined as

$$R_d = 20 \log_{10} \frac{M_d}{M_r}$$

The sound field in very reverberant rooms can be considered a diffuse sound field.

2. DESCRIPTION

2.1. GENERAL

The Types 4144 and 4145 microphone cartridges are supplied in a mahogany case with an individual calibration chart and a protective silica gel cap UA 0135. The cap serves as a dust cover and keeps the air in the microphone dry during storage.

The Type 4146 microphone cartridge is supplied in a special plastic container which contains a silica gel to keep the air dry during storage. In the lid of this container is a key which may be used to tighten or undo the threaded collar which seals the silicone rubber ring against the back of the microphone. The 4146 microphones are also supplied with an individual calibration chart.

The silica gel in both the microphone cap UA 0135 and the container for the 4146 is blue when dry but turns pink as it becomes water saturated. Saturated gel may be dried by heating. This is easily done by placing the cap or container in an oven at 100° – 135°C for 1/2 – 1 hour. The gel may be reactivated in this manner as many times as required, but unnecessary saturation may be prevented by keeping the 4146 container closed except when replacing or removing the microphone, and by keeping the microphone cap in the cartridge hole of a closed microphone box while the microphone is in use.

The three cartridges have basically the same mechanical construction, differing only in the state of the pressure equalization and in the damping of the diaphragm resonance. These differences are due to the different purposes of the three microphones. The 4144 is designed especially for sound pressure measurements in closed volumes, the 4145 for free field measurements, and the 4146 for very low frequency (as low as 0.1 Hz) sound pressure measurements.

A cutaway view of the 4146 is shown in Fig.2.1. A silicon rubber seal, with accompanying washer, prevents static pressure equalization and lowers the low frequency response to between 0.01 Hz and 0.1 Hz. Fig.2.2 shows an exploded view of the 4144/45 which do not have the seal and washer

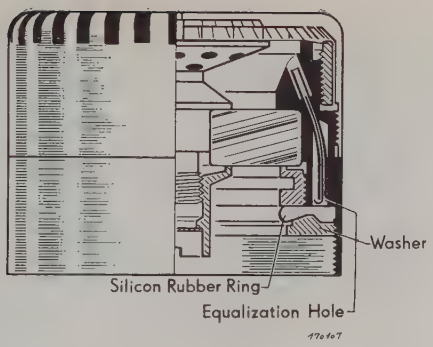


Fig.2.1 Cut Away View of 4146 Showing Sealed Pressure Equalization Vent.

that the 4146 does. For Types 4144 and 4145, however, a kit with sealing gasket UA 0240 is available to extend the frequency range down to 0.1 Hz. This low frequency response is not guaranteed as is the low frequency response of the 4146.

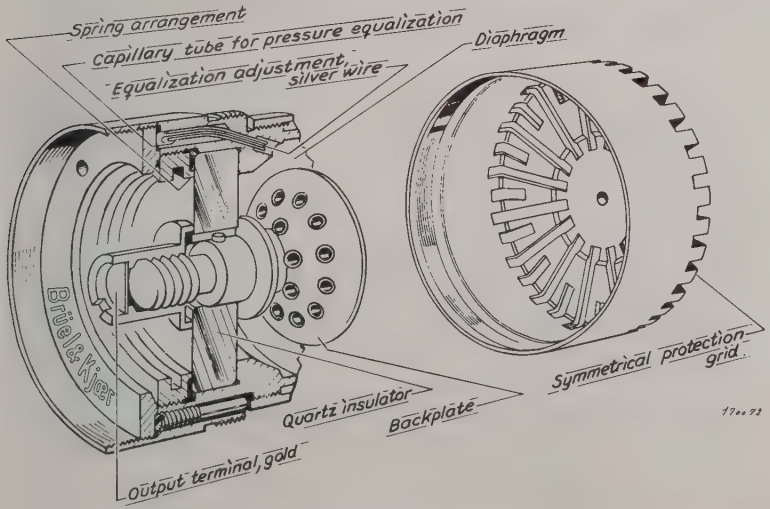


Fig.2.2 Exploded View of Microphone Types 4144 and 4145

The damping of the diaphragm resonance is due to the movement of air between diaphragm and back plate and therefore depends on the geometry of the back plate and the mechanical tension in the diaphragm.

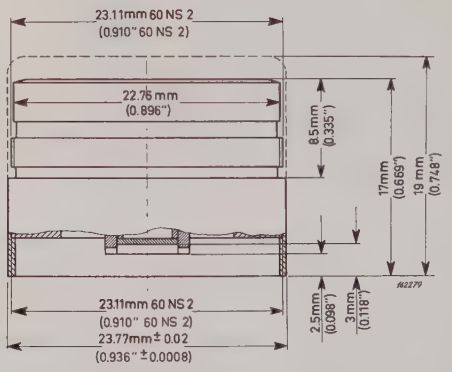


Fig.2.3 Dimensions of the Type 4144/45/46 Cartridges.

2.2. CHARACTERISTICS

The most important characteristics of the microphones are individually calibrated at the factory. A calibration chart similar to the ones shown in Fig.2.4 accompanies each cartridge.

Sensitivity

The open circuit sensitivity, which is the sensitivity when the microphone is not loaded by any preamplifier, stray capacitance, etc., is given on the calibration chart which is supplied with each microphone. This sensitivity is measured at 250 Hz. The nominal open circuit sensitivity is 50 mV per N/m^2 but the actual sensitivity with any preamplifier may be calculated from the open circuit sensitivity S_o given on the calibration chart, the cartridge capacitance C_t, and the effective input capacitance C of the preamplifier. Thus the sensitivity of the microphone with any preamplifier is

$$S_1 = S_o \cdot A \cdot \frac{C_t}{C_t + C}$$

where A is the voltage gain of the preamplifier.

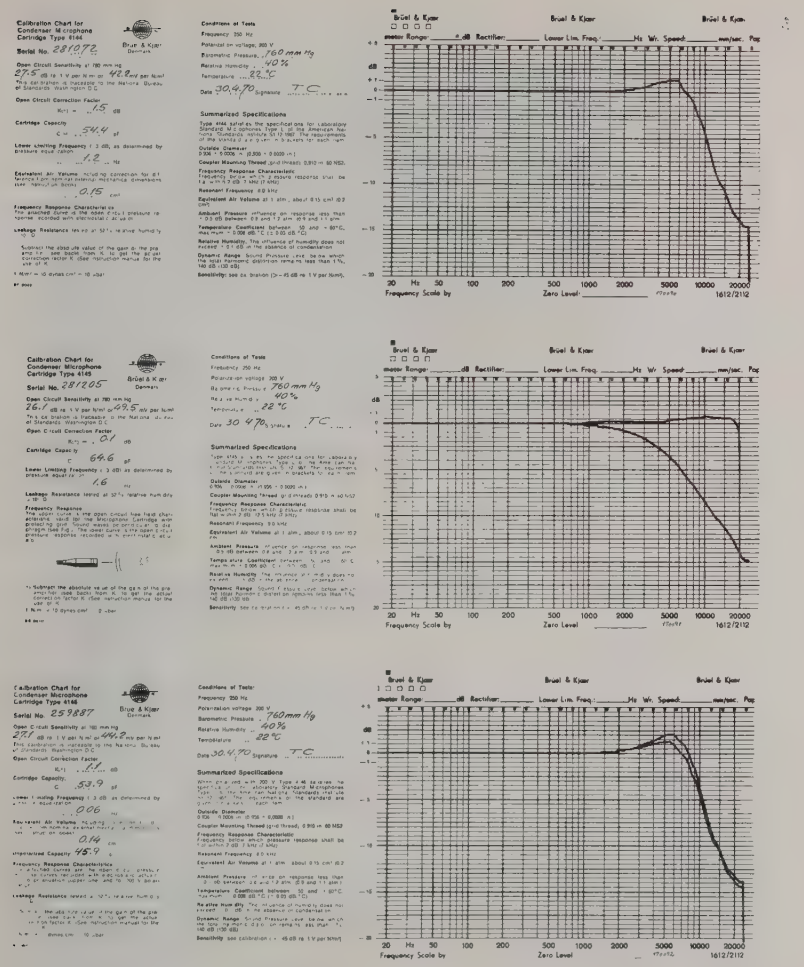


Fig.2.4 Typical Calibration Charts as Supplied with Each Microphone

Correction Factor

Many B & K instruments are calibrated for a standard microphone sensitivity of 50 mV per N/m^2, i.e. −26 dB relative to 1 V per N/m^2. Since the microphone, or microphone plus preamplifier, may differ from this sensitivity a correction factor must be added to the meter reading of these instruments to get the actual level. In other words, the sound level in dB measured by an instrument calibrated to a 50 mV standard microphone sensitivity is equal to the meter reading of the instrument plus the attenuator setting, if any, plus the correction factor K. K is the correction factor for the combination of microphone plus preamplifier and includes K_o, the correction factor of the microphone alone, which is given on the calibration chart supplied with the microphone.

$$K = K_o - G$$

where G is the absolute value of the gain of the preamplifier in dB and includes the effect of transducer capacitance. In other words

$$G = g + 20 \log_{10} \frac{C_t}{C + C_t}$$

where C_t is the microphone capacitance (given on the calibration chart), C is the effective input capacitance of the preamplifier, and g is the gain in dB of the preamplifier alone.

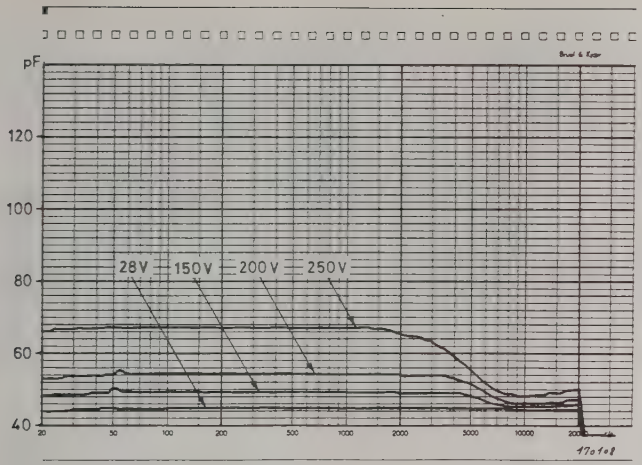
On the back of the calibration chart supplied with each microphone is a table of some of the typical gains of various B & K preamplifiers and of the input stages of B & K sound level meters.

Cartridge capacitance

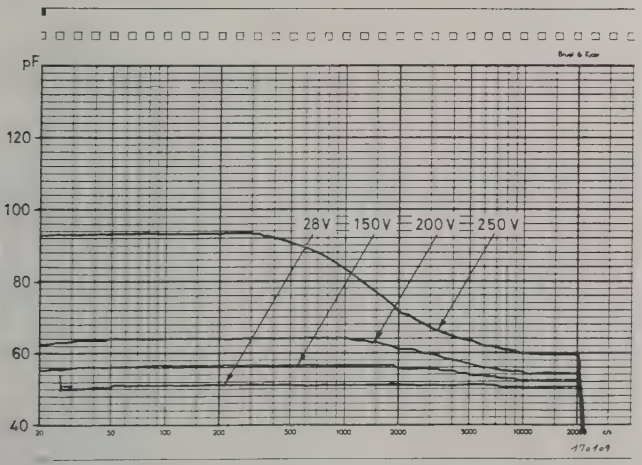
The capacitance given on the calibration chart is measured at 250 Hz with a polarization voltage of 200 V. Because of the mass of the diaphragm, the capacitance is frequency dependent. Typical variation with frequency is shown in Fig.2.5.

Low Frequency Limit (−3 dB point)

The low frequency limit of the cartridge is determined by the pressure equalizing arrangement. In the case of the 4144 and 4145 cartridges, the low frequency limit is between 1 and 2 Hz. The 4146 cartridges have the



a) 4144/46



b) 4145

Fig.2.5 Variation of Capacitance with Frequency

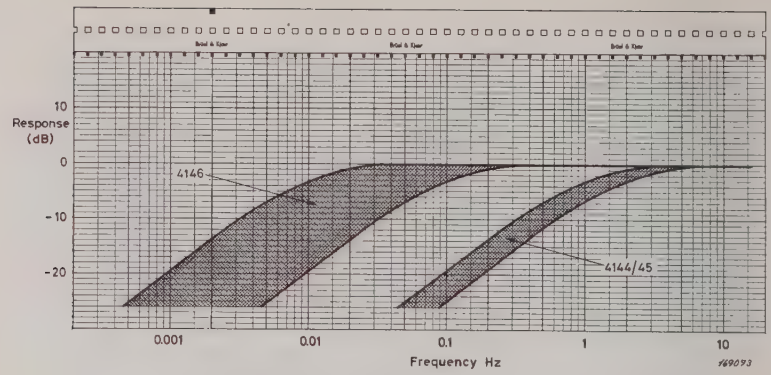


Fig.2.6 Low Frequency Limits

equalization vent sealed by a silicon rubber sealing ring and have, therefore, a low frequency limit between 0.01 Hz and 0.1 Hz (Fig.2.6).

Using the Sealing Kit UA 0240, the 4144 and 4145 cartridges equalization vent can be sealed to reduce the low frequency limit to be similar to the 4146.

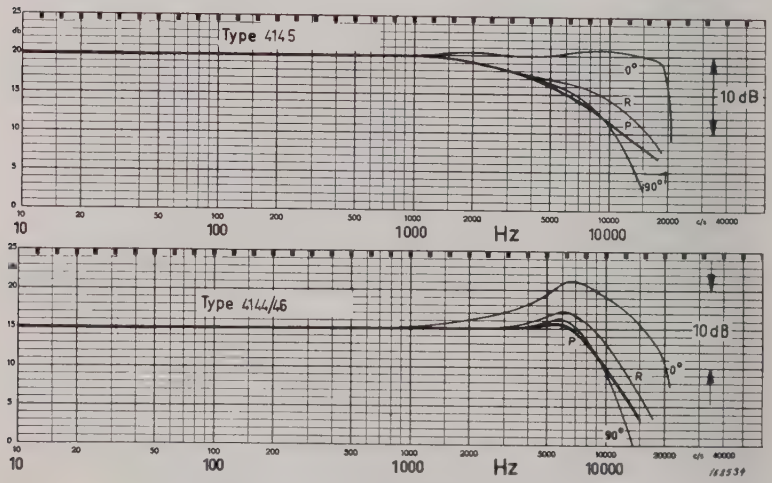


Fig.2.7 High Frequency Limits

Leakage Resistance

The leakage resistance of the insulation in the cartridge is measured at 200 V, 52% relative humidity. The resistance is normaly well above $10^{15}\ \Omega$, but if the quartz insulator is dirty or damp, it may become lower than this.

Frequency Response

The calibration chart provided with each microphone cartridge gives the individual frequency response to sound pressure determined by the electrostatic actuator method. (See Fig.2.4 and Chapter 4). The frequency response given on the calibration chart is the open circuit response and the response of whatever preamplifier is to be used must be added if extremely accurate response is required, especially below 20 Hz.

The free-field response at a particular incidence angle is obtained by adding to the actual pressure response the relative free-field correction given in Figs. 2.8 and 2.9.

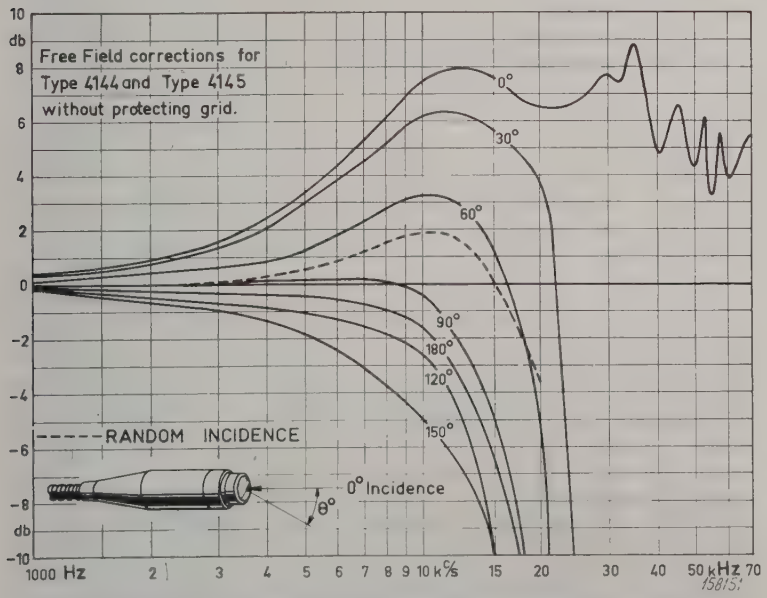


Fig .2.8 Free Field Corrections for Microphone without Protecting Grid (electrostatic actuator method of pressure calibration)

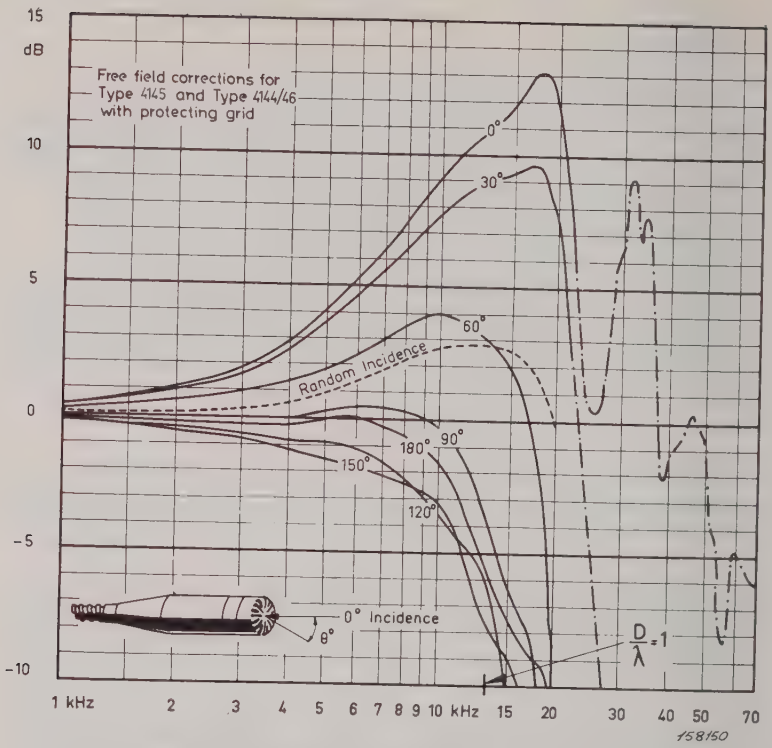


Fig.2.9 Free Field Correction for Microphone with Protecting Grid (electrostatic actuator method of pressure calibration)

This is done on the individual chart for the 4145 cartridges at 0° incidence (with grid) since the flatness (within ± 1.5 dB) of this characteristic is the basis of the adjustment of the pressure response. In Fig.2.7 the two cases 0° and 90° incidence, and the random incidence (diffuse field) characteristics, have been represented for comparison purposes in a typical case. Characteristics at other angles of incidence may be deduced from the particular pressure response and the curves of Fig.2.8 and 2.9. It should be noted that when reciprocity calibration of microphones is carried out according to the ANSI* Standard S1.10–1966 the pressure response should be determined with the microphone diaphragm loaded by a very high acoustic impedance. This is not the case when the pressure response is determined by the electrostatic actuator method and the free-field correct-

*ANSI is American National Standards Institute

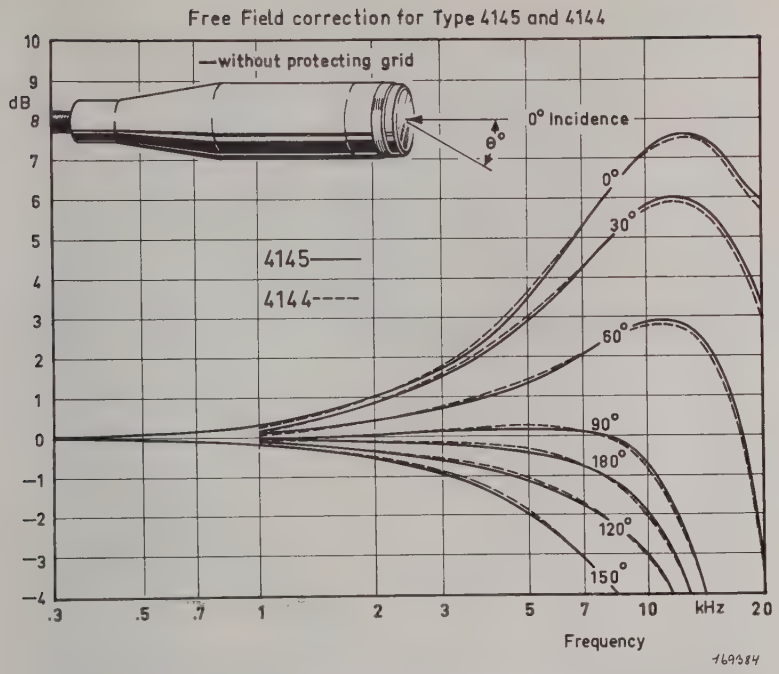


Fig.2.10 Free Field Corrections for Microphone without Protecting Grid (ANSI method of pressure calibration)

ion curves are therefore not the same. Figs.2.10 and 2.11 give the free field correction to be added to the pressure characteristic when this is determined by the ANSI method.

The pressure increase which is caused by the reflections of free-field sound waves on the microphone diaphragm becomes appreciable above 1 kHz. The corresponding correction curves, which are valid for all three cartridges are given in Figs.2.8 to 2.11.

When a Random Incidence Corrector or a Nose Cone is mounted on the microphone, however, the free-field corrections are more independent of the incidence. This is of great interest when using the microphones in complex sound fields. (See Sec. 5.1 and 5.2). The random corrections are calculated according to the recommendations of the IEC for Sound Level Meters. (IEC 123 § 8.2).

This gives: $\bar{S}$ = random incidence sensitivity
S_n = sensitivity at n° angle of incidence

Thus $S^2 = 0.018\,S^2_0 + 0.129\,S^2_{30} + 0.224\,S^2_{60} + 0.258\,S^2_{90} + 0.224\,S^2_{120} + 0.129\,S^2_{150} + 0.018\,S^2_{180}$

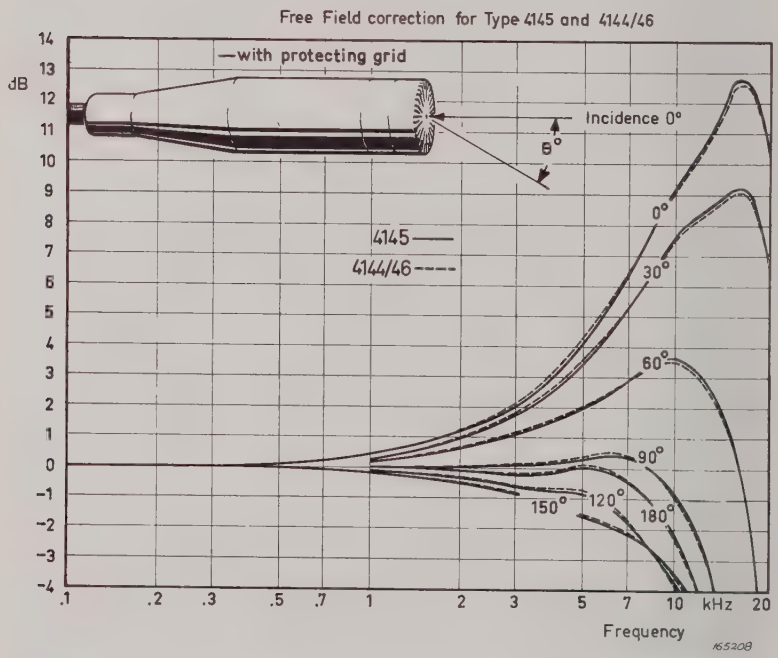


Fig.2.11 Free Field Corrections for Microphone with Protecting Grid (ANSI method of pressure calibration)

Directional Properties

As the three types of cartridge have the same mechanical dimensions their directional properties are identical, Fig.2.12.

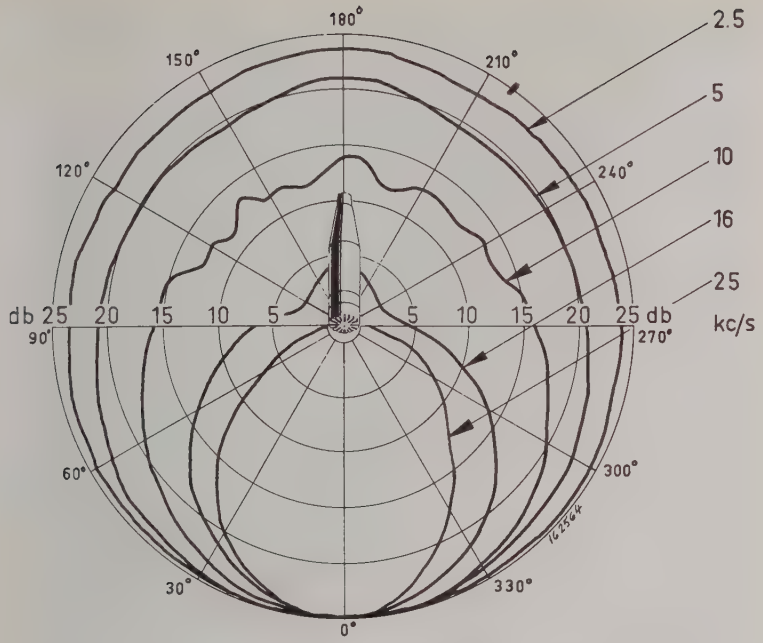


Fig.2.12 *Typical Directional Characteristics for 1" Microphone with Protecting Grid.*
Note: Better omnidirectional properties are obtained if the protecting grid is replaced by a Random Incidence Corrector UA 0055 or a Nose Cone UA 0051

Phase Characteristics

The pressure response phase angle characteristic for the complete microphone, that is the cartridge and a preamplifier, can be seen in Fig.2.13. The diaphragm resonance (90° phase angle) is typically 10 kHz for Type 4145 and 8 kHz for Types 4144 and 4146.

At diaphragm resonance the diaphragm is critically damped in the 4144 and 4146 but is over damped in the 4145.

It should be noted that for positive polarization voltage such as is used in normal B & K preamplifiers, the output signal will be negative for positive

pressure on the diaphragm. For other systems consult the preamplifier instruction manual for information regarding this subject.

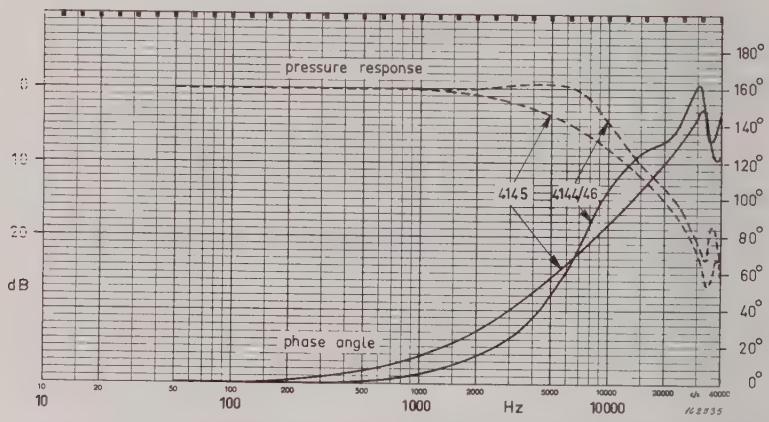


Fig.2.13 *Typical Phase Angle and Frequency Response of the Pressure Characteristics of Microphone Types 4144/45/46*

Dynamic Range. Noise and Distortion

The lower limit of the dynamic range is set by the electrical noise of the preamplifier. This noise will be a function of the equivalent bandwidth. (The narrower the equivalent bandwidth, the lower the noise, hence the lower the limit of the dynamic range). See Tables 1—6 Chapter 3.

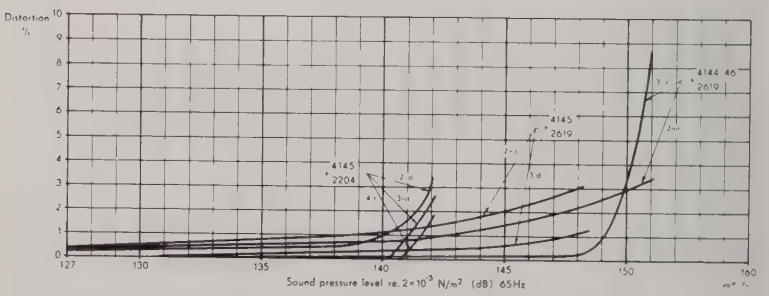


Fig.2.14 *Typical Distortion Curves*

The upper limit of the dynamic range depends on the amount of harmonic distortion which can be tolerated. Fig.2.14 shows the distortion with preamplifiers 2619 and Sound Level Meter 2204.

The distortion level also depends on the capacitance (i.e. length of the cable) connected to the output of the preamplifier, (see the instruction manual for the preamplifiers). The limits shown in Fig.2.14 are for short cables (2 m (6.6 ft)).

It is recommended not to expose the cartridges to levels higher than 160 dB, as higher pressures may cause damage.

Polarization Voltage

All the data supplied for the 4144/45 cartridges are for a polarization voltage of 200 V. If the microphones are used in conjunction with normal B & K equipment the polarization voltage will be 200 V DC assuming the equipment has been adjusted correctly.

The sensitivity and frequency response will differ with polarization voltage, as shown in Figs.2.15 and 2.16. Any voltage greater than 250 V applied across the polarization terminals will damage the microphone.

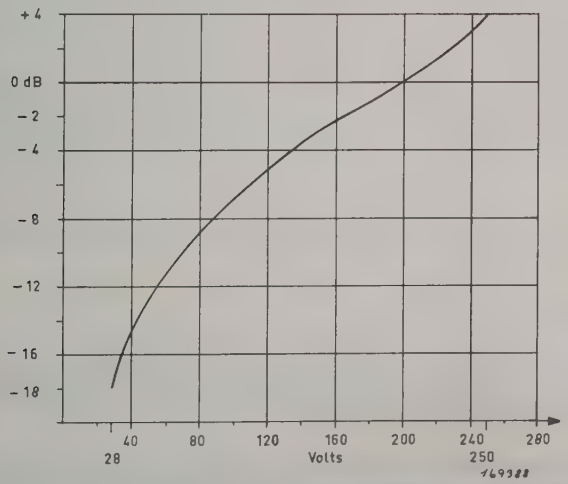
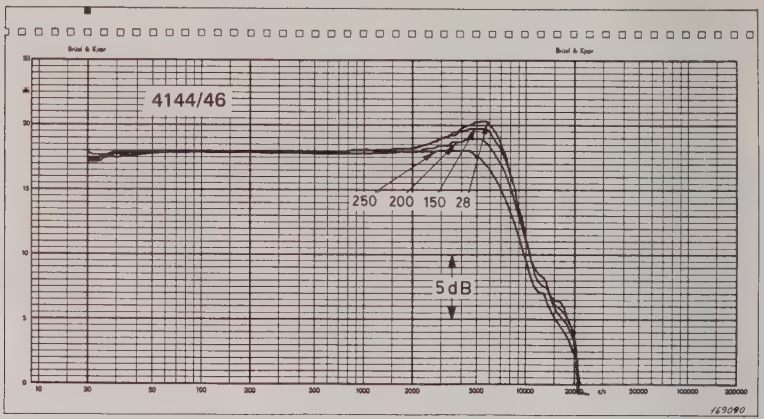


Fig.2.15 Sensitivity as a Function of Polarization Voltage



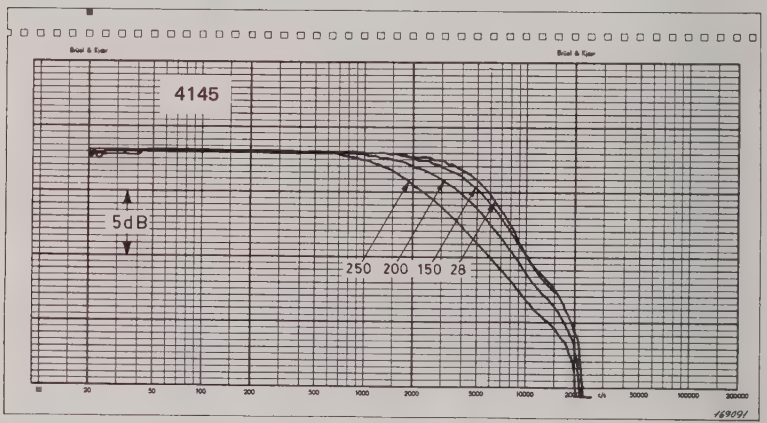


Fig.2.16 Frequency Response at Various Polarization Voltages

Long Term Stability

Microphone sensitivity may change during a long period of time even if no accident or mishandling has occurred. These changes are due to changes in the materials making up the device.

The major contributions to change in response is metal flow in the diaphragm, "sag". This "sag" is noticeable as a decrease in diaphragm tension

and a resultant (inversely proportional) increase in compliance characterized by increased sensitivity especially for frequencies below the diaphragm resonant frequency. Since heat softens metal this flow or "sag" appears fastest at high temperatures, the resultant sensitivity increase at 150°C is about 0.2 dB/hour.

Fig.2.17 shows an extrapolated plot of sensitivity stability as a function of temperature, thus allowing calculation of the approximate stability at any temperature within the range. For example, the drift at room temperature is about 0.2 dB per 1000 years. For further information on the subject please refer to B & K Technical Review No. 2, 1969.

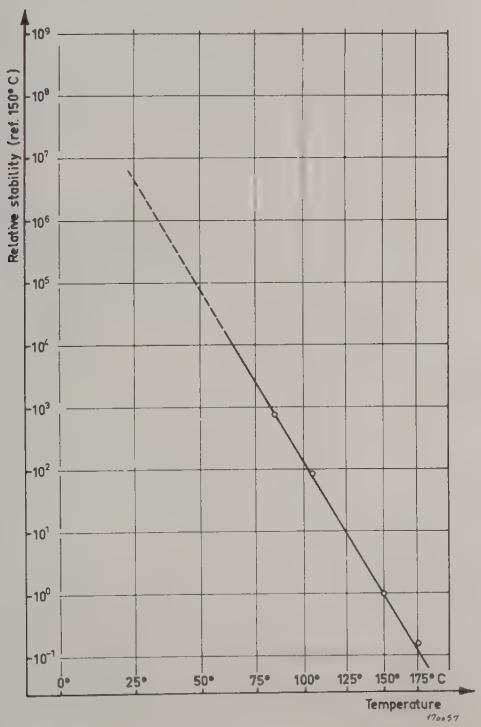
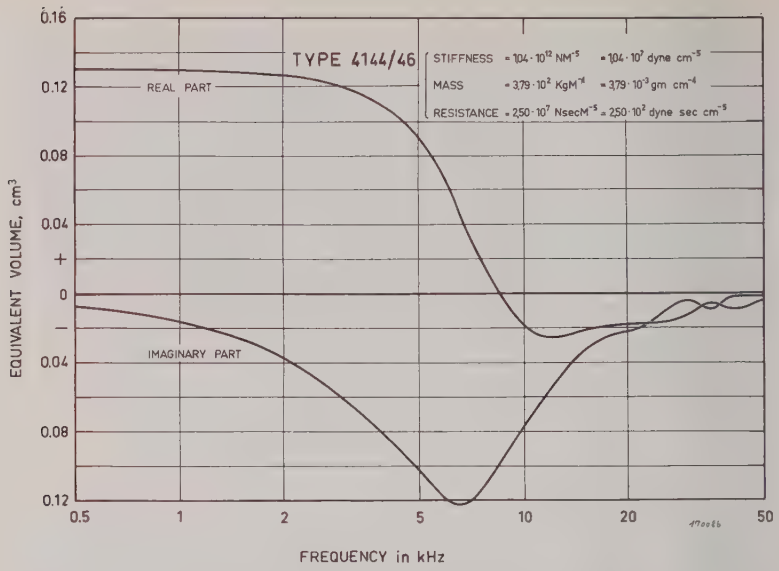


Fig.2.17 Long Term Stability (Hours vs temperature)



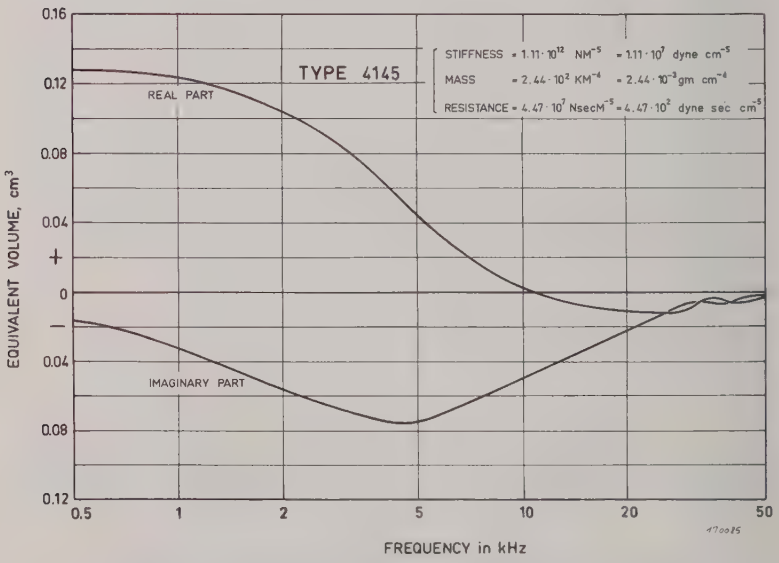


Fig.2.18 Frequency Dependence of Equivalent Volume

Equivalent volume

In dealing with closed cavity measurements (coupler measurements) it is usual to express the acoustic driving-point impedance (ratio of uniform sound pressure over the diaphragm to volume velocity of the diaphragm) of the microphone in terms of an equivalent volume V_e.

$$V_e = \frac{\gamma P}{j \omega Z_a}$$

where
γ = ratio of specific heats
P = ambient pressure
Z_a = acoustic driving point impedance
ω = 2π times the frequency

The frequency dependence of the equivalent volume indicated in the above equation is illustrated in Fig.2.18.

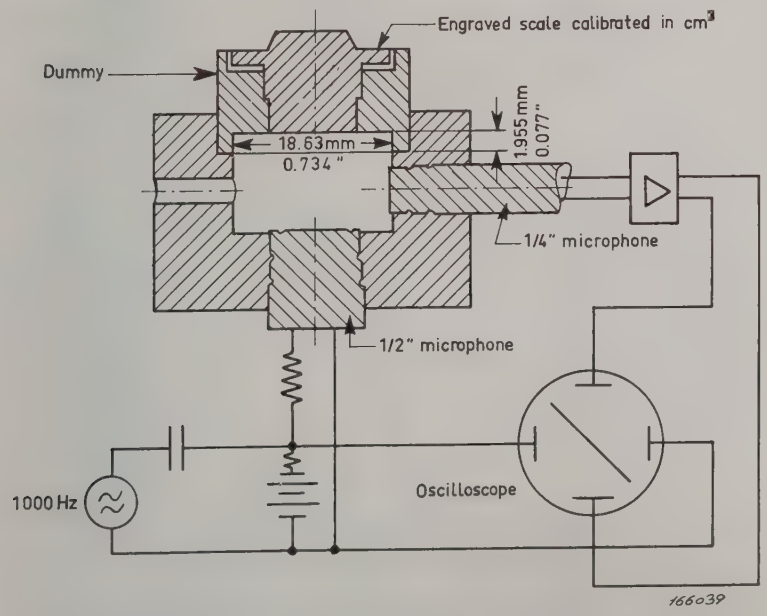


Fig.2.19 Determination of Equivalent Air Volume of a Microphone

The equivalent volume is important for accurate measurements being made in a closed volume. The way in which the equivalent volume may be measured is illustrated in Fig.2.19.

The microphone to be measured is placed on top of the coupler (the position occupied by the dummy in the drawing). The generator is adjusted until the input voltage on the 1/2" transmitter condenser microphone cart-

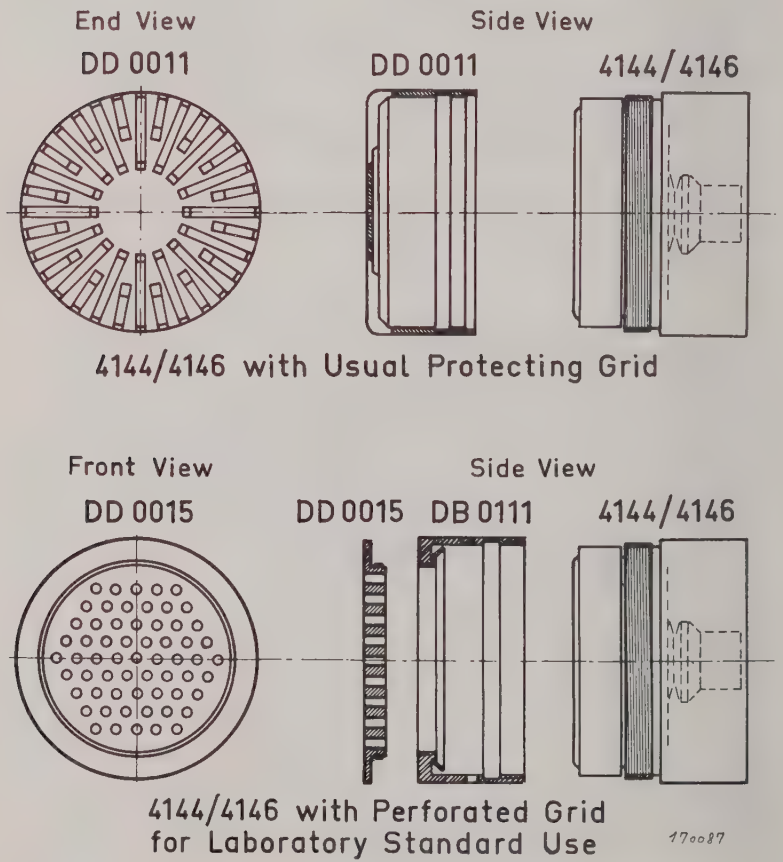


Fig.2.20 Modification of the Type 4144/46 for Use as Laboratory Standard

ridge is in phase with the output of the 1/4" receiver condenser microphone cartridge. Now the microphone under test is replaced by the dummy, and the calibrated centre piece of this is adjusted until the in-phase condition between 1/2" and 1/4" cartridges is obtained again. The equivalent volume can then be read directly from the scale on the dummy cartridge.

It should be noted that the equivalent volume specified for the B & K condenser microphones Type 4144 and 4146 is given on the data sheet enclosed with the microphone.

This equivalent volume is stated as being the amount in cm^3 by which the microphone with coupler adaptor ring and diaphragm compliance, is larger than a nominal front cavity 1.863 cm in diameter and 0.1955 cm deep.

This means that no further correction for the coupler volume is necessary when the equivalent volume specified in the data is used.

Comparison between Types 4144/46 and Type WE 640 AA

The characteristics of the B & K 1 inch Condenser Microphone Types 4144/46 are very similar to those of the microphone Type WE 640 AA which is also used as a laboratory standard. By a simple external modification the normal incidence free field characteristics of the microphones can be made identical. This modification consists of mounting an adaptor (DB 0111) and perforated grid (DD 0015) in place of the usual protecting grid (DD 0011) used with the Type 4144/46 microphones. Fig.2.20 illustrates this modification. The resulting change in frequency characteristics is seen in Fig.2.21. The adaptor DB 0111 is included in the Couplers Type DB 0160 and DB 0161 (see Chapter 5).

2.3. ENVIRONMENTAL EFFECTS

Temperature

The effect of temperature on the sensitivity is described in the section Long-term Stability. This is a permanent change in sensitivity which takes place, more rapidly at higher temperatures. The small reversible changes in sensitivity and frequency response which occur during operation at elevated temperatures are shown in Fig.2.22.

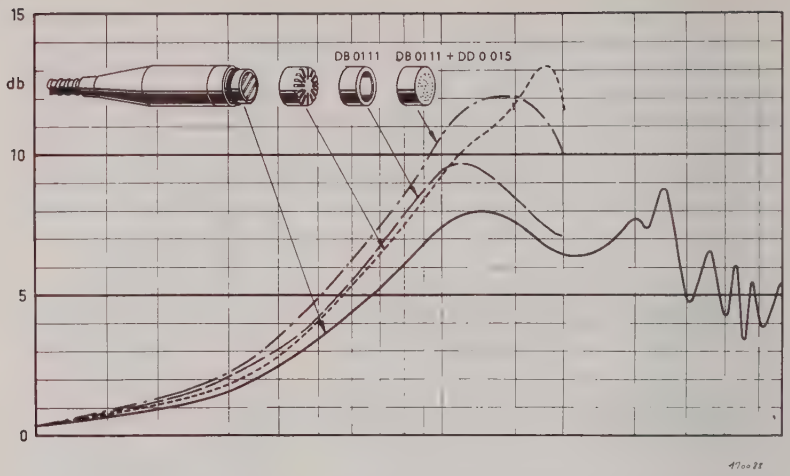


Fig.2.21 *Free Field Corrections for Microphone Types 4144 and 4146 with Adaptors for Use as Laboratory Standard Microphone (electrostatic actuator method of pressure calibration)*

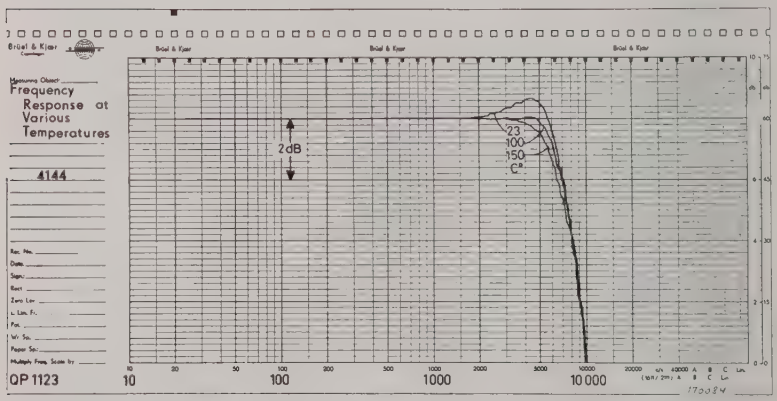


Fig.2.22 *Frequency Response at Various Temperatures*

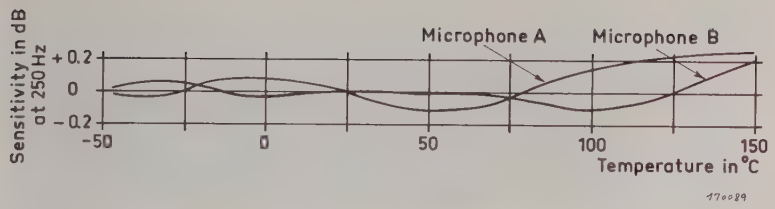


Fig.2.23 Temperature Dependence of Sensitivity

The changes are the result of small expansions and contractions of the materials of the microphone, especially the housing and back plate. These dimensional changes result in a change in the distance between the diaphragm and the back plate and in changes in diaphragm tension. The effect of these changes are normally less than ± 0.2 dB throughout the usable temperature range but are nearly random within those limits varying unpredictably from one unit to the next as illustrated in Fig.2.23.

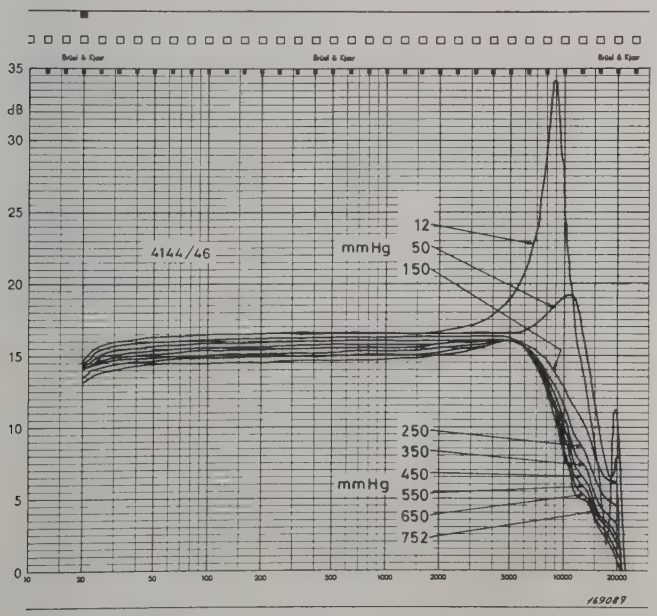


Fig.2.24 Frequency Response at Various Ambient Pressures

Ambient Pressure

One component of the stiffness of the vibrating system comes from the air inside the microphone. As the air pressure decreases this stiffness decreases so that at very low pressures the sensitivity of the microphone increases about 1.5 to 2 dB. The sensitivity increases most around the resonant frequency of the diaphragm. The static ambient pressure affects the

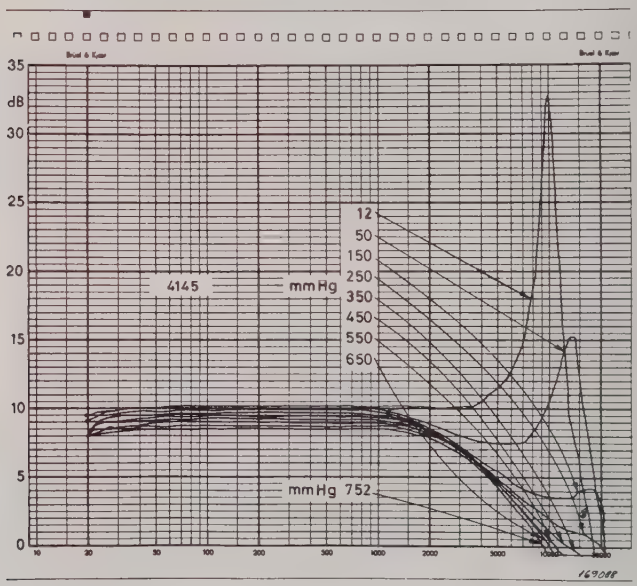


Fig.2.24 Frequency Response at Various Ambient Pressures

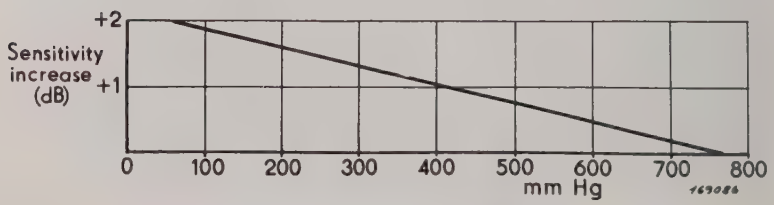


Fig.2.25.a Pressure Dependence of Sensitivity at 250 Hz

frequency response and sensitivity of the cartridges as shown in Figs.2.24 and 2.25. The Sensitivity in Fig.2.25 was measured at 250 Hz and should not be applied at any other frequency without reference to the frequency response variations.

Humidity

The actual humidity of the air in which the microphone is used has a negligible effect on the characteristics. In conditions of high humidity, however, condensation can take place in the microphone if the cartridge is subjected to temperature variations. Water droplets in the microphone can cause intermittent shorts and large amounts of electrical noise especially at low frequencies. The heat generated by a preamplifier helps to diminish this problem. A description of the phenomena can be found in B & K Technical Review No. 1, 1960.

For better reliability the microphone should be stored with a silica gel to ensure that the air in the microphone remains dry when the unit is not in use. (See Sec.2.1).

Vibration

The influence of vibration depends on the direction in which it is applied to the microphone. It is at a maximum when the vibration is perpendicular to the diaphragm, and is determined mainly by the mass of the diaphragm and the air column on both sides of it. A vibration level of 1 g (RMS) perpendicular to the diaphragm will produce an output equivalent to 88 dB SPL.

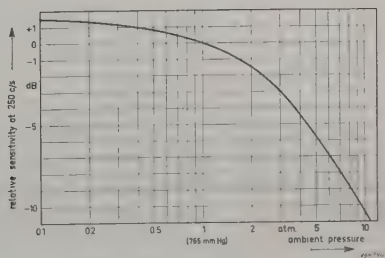


Fig.2.25.b Pressure Dependence of Sensitivity at 250 Hz

3. USE WITH OTHER INSTRUMENTS

3.1. GENERAL

The Condenser Microphones Type 4144/45/46 are designed for use with Microphone Amplifiers Type 2603/4/6, Frequency Analyzer Type 2107 or Frequency Spectrometers type 2112/13, all requiring a suitable preamplifier, or with Precision Sound Level Meter Type 2203 or Impulse Precision Sound Level Meter Type 2204 which contain their own preamplifier.

3.2. PREAMPLIFIERS

The 1" condenser microphones are designed to be screwed onto the input of B & K Preamplifiers Types 2615/2619 when equipped with Adaptor DB 0375, and on to older Types 2612 and 2613. All of the preamplifiers derive their power externally, from a measuring instrument such as the B & K Measuring Amplifiers, Analyzers, or Spectrometers, or from a Microphone Power Supply. The seven pin preamplifier plug is simply plugged into the front panel of the measuring instrument (Socket marked "Condenser Microphone") or the input of the Power Supply.

Complete information on the preamplifiers is available in the relevant instruction manuals.

A brief summary of the frequency response and dynamic range of the 2615, 2617 and 2619 may be found in the tables at the end of this chapter.

3.3. MEASURING AMPLIFIERS

The B & K Measuring Amplifiers Types 2603/06/07 are designed for accurate sound level measurements in conjunction with the B & K microphones and preamplifiers. These amplifiers provide the power for the microphone and preamplifier, and accurately measure the signal level from the microphone.

Types 2606/07, in particular, have a very accurate RMS capability for

signals with crest factors up to 40 for the 2606 and up to 5 for the 2607. They also provide impulse and RMS meter hold indications to the DIN 45 633 part 2 specifications (proposed IEC standard for impulse noise). Hence accurate impulsive noise measurements can be made with this amplifier. For shock measurements, however, a very low frequency response is required, this measuring amplifier has a low frequency cut-off as high as 2 Hz.

3.4. THE MICROPHONE CARRIER SYSTEM TYPE 2631

The microphone carrier system has been designed for sound measurements in the frequency range 0 – 200 kHz. With the Type 4146 microphone it is especially useful for measuring low frequency pressure variations such as those found in sonic booms, thunderstorms, wind tunnels and pressure chambers. Microphones Type 4144 and 4145 can also be sealed to give similar characteristics. (See Sec.2.1).

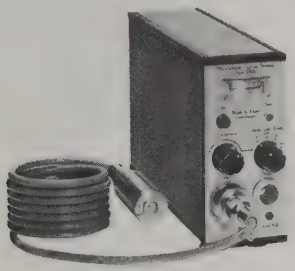


Fig.3.1 Microphone Carrier System Type 2631

The microphone carrier system consists of a power supply module and a microphone head with cable and plug (ZB 0011). The power supply module contains an output amplifier, peak indicating meter, etc. The peak indicating meter detects the signal level and indicates overload. The microphone head contains a tuned circuit oscillator and preamplifier. The two units are connected by a two meter long cable. The condenser microphone is screwed onto the microphone head and its capacitance determines the resonant frequency of the tuned circuit. The resonant frequency is 10 MHz and the circuit is driven by a 10 MHz crystal controlled oscillator. Small changes in the microphone capacitance caused by sound pressure acting on the diaphragm will modulate the resonant frequency of the tuned circuit. Thus the

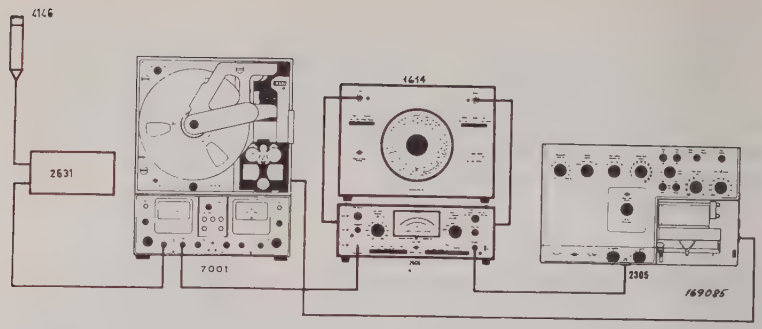


Fig.3.2 Instrumentation for Observation of Sonic Booms, Thunderclaps, etc.

circuit acts as an F.M. detector which feeds the detected signal to the preamplifier. To enable 1" microphone cartridges with different capacitances to be used, automatic compensation is incorporated. A feedback amplifier controls the voltage applied to two variable capacitance diodes, which are included in the tuned circuit. The feedback amplifier is a Miller integrator whose time constant determines the lower limiting frequency of the tuned circuit. This feedback also produces automatic AC balance. Balance in the DC mode is obtained manually with the aid of the monitoring meter. Four lower limiting frequencies can be selected, 0, 0.01, 0.1 and 1 Hz.

An indicating or recording instrument with response down to DC is required if the low frequency components of the signal are to be observed. An oscilloscope is suitable, or an FM Tape recorder or pen recorder can be used to record the signal.

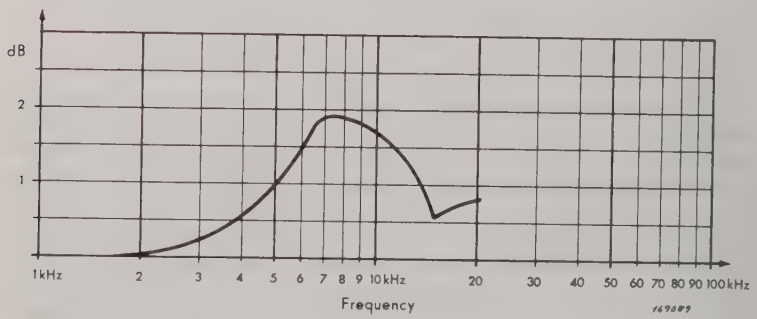


Fig.3.3 Correction to 4144 Pressure Response When Used with Carrier System Type 2631

If the Type 4144 microphone is used with the Carrier System the pressure response calibration must be corrected because of the 10 V AC polarization voltage rather than the usual 200 V DC. The correction is shown in Fig.3.3. A calibration with AC polarization voltage is supplied with each Type 4146 microphone.

3.5. FREQUENCY ANALYZERS

The B & K frequency analyzers 2107 and 2112 have an amplifier section similar to the 2603, the amplifier section of the 2113 is similar to the 2606, and the amplifier section of the 2114 is similar to the 2607. A preamplifier is required between the microphone and the analyzer input.

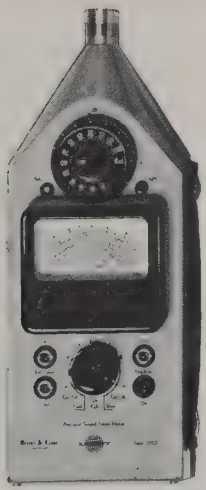


Fig.3.4 Precision Sound Level Meter Type 2203

3.6. PRECISION SOUND LEVEL METER TYPE 2203

The Sound Level Meter Type 2203 includes Condenser Microphone Type 4145 giving a highly accurate system suitable for outdoor use as well as for precise laboratory measurements. It is portable, battery driven and completely self contained for ordinary sound level measurements. In conjunction with the B & K Octave Filter Set Type 1613 (31.5 Hz to 31.5 kHz) the

instrument becomes an easily operated frequency analyzer. It is designed to fall within IEC specifications for precision sound level meters. The dynamic range covers most sound levels encountered in practice. A source follower containing a low noise silicon field effect transistor (FET) and two other silicon transistors is inserted prior to the input amplifier of the 2203 in order to correctly load the condenser microphone. For remote mounting of the microphone from the 2203 the microphone may be connected to the 2203 via extension cable AO 0033 (3 m).

Detailed information on the 2203 will be found in its instruction manual but a summary of some of the characteristics may be found in the tables at the end of this chapter.

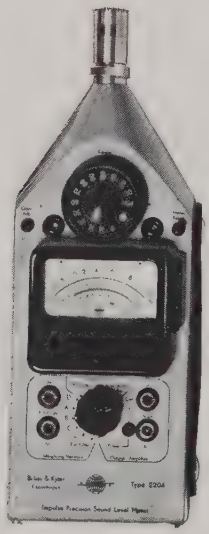


Fig.3.5 Impulse Precision Sound Level Meter Type 2204

3.7. IMPULSE PRECISION SOUND LEVEL METER TYPE 2204

The 2204 which also includes the 4145 provides the same functions as the 2203 and is able to measure impulsive noise. The meter meets the requirements of the new German standard for impulse sound level meters

(DIN 45 633-2) and those of the IEC proposal. A D-weighting network for the measurement of aircraft noise is built in. The input impedance is 20 G Ω paralleled by 0.25 pF and the dynamic range can extend down to 15 dB. (A weighting network). Using the Type 4146 with this instrument it is possible to measure down to 2 Hz. For remote mounting of the microphone from the 2204, the input stage of the meter and the microphone are both removed and attached by means of an extension cable, AO 0027/28/29. This makes the 2204 very suitable for operation under free field conditions.

Detailed information on the 2204 is available in its instruction manual and a summary of its frequency and dynamic ranges is in the tables at the end of this chapter.

3.8. TWO CHANNEL MICROPHONE SELECTOR TYPE 4408

The Two Channel Microphone Selector Type 4408 is designed especially for use with B & K condenser microphones and enables the output from one or the other of two microphones to be alternately switched to the input of a single amplifier. (The B & K instruments Types 2603/04/06/07, 2107, 2112/13/14, 2211/12, 2801 are able to power two microphones from a single CONDENSER MICROPHONE input socket).

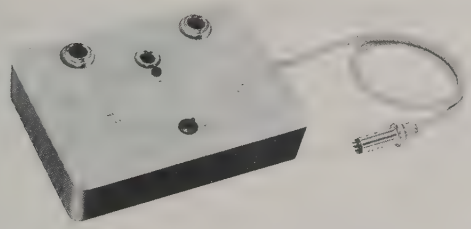


Fig.3.6 Two Channel Microphone Selector Type 4408

A recording of two phenomena, e.g. the sound pressure at two different points in a sound field, can thus be obtained on a level recorder. The microphone selector is mounted in a metal case as shown in Fig.3.6 and contains a toggle switch for manual operation of a relay which selects one or the other of the microphone inputs. The relay is powered from the microphone power supply. The selector may also be remotely controlled. The toggle switch is then switched to position "2", and an external control

switch connected to the terminals marked EXTERNAL CONTROL. The external switch then replaces the function of the toggle switch.

Note: The filament voltage supply wiring in the 4408 provides for series connection of the cathode follower filaments, hence one cathode follower cannot be used alone with this instrument.

3.9. MICROPHONE POWER SUPPLY TYPES 2801/03/04

The Microphone Power Supply is used in cases where B & K Amplifiers or Analyzers are not required or where extremely long extension cables must be used between the microphone and the succeeding amplifier. The power supply unit supplies the necessary bias and polarization voltage for the microphones and preamplifiers. The power supply units are heavily stabilized for variations in line voltage and may be operated from power outlets with 100–115–127–150–220 or 240 Volts (50 to 400 Hz). Except the 2804 which is battery operated.

A Microphone Power Supply can also be employed in conjunction with the above-mentioned Microphone Selector Type 4408. For further details the reader is referred to the appropriate instruction manual.

3.10. INSERT VOLTAGE CATHODE FOLLOWER TYPE 2617

The Type 2617 is designed to allow calibration of B & K condenser microphones or other similar microphones by the "Insert Voltage" method. For this reason the thread for the cartridge is isolated from the cathode follower housing and a switch allows the shield to be either grounded or driven. (See Fig.3.7).

With the Type 2617 connected to the Insert Voltage Junction Box ZH 0007 it is possible to measure the "Open Circuit Voltage" of the microphone as specified in the ANSI Standard S1.10–1966.

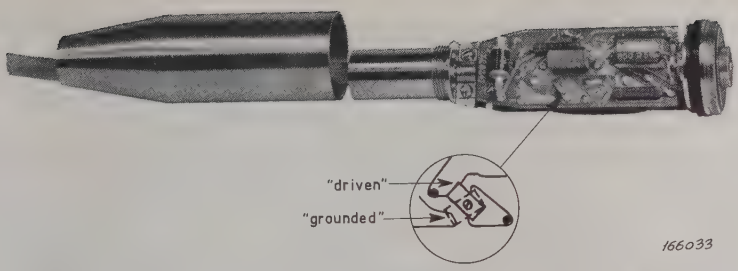


Fig.3.7 Exploded View of Insert Voltage Cathode Follower Type 2617 with Shield Switch Indicated

3.11. FREQUENCY AND DYNAMIC RANGE OF VARIOUS INSTRUMENTS WHEN USED WITH MICROPHONE TYPES 4144/45/46

1. Precision Sound Level Meter Type 2203

Type	Frequency Range	Dynamic Range* (from 5 dB above noise level to max. sinusoidal RMS voltage, 4% distortion)	
4144	10 Hz to 7.5 kHz ± 2 dB (Pressure Response)	Linear	38–140 dB
		A	19–140 dB
		B	21–140 dB
		C	28–140 dB
4145	10 Hz to 18 kHz ± 2 dB (Free Field Response) (0° Incidence)	Octave Filter f > 500 Hz	14–140 dB
		1/3 Octave Filter f > 500 Hz	10–140 dB

* Dynamic Range frequencies refer to noise band width.

2. Impulse Precision Sound Level Meter Type 2204

Type	Frequency Range	Dynamic Range (from 5 dB above noise level to max. sinusoidal RMS voltage, 4% distortion)	
4144	4 Hz to 7.5 kHz ± 2 dB (Pressure Response)	Linear	36–140 dB
		A	15–140 dB
		B	19–140 dB
		C	22–140 dB
		D	25–140 dB
4145	4 Hz to 18 kHz ± 2 dB (Free Field Response) (0° Incidence)	Octave Filter (1613) $f > 500$ Hz	12–140 dB
		1/3 Octave Filter (1614) $f > 100$ Hz	15–140 dB
4146	2 Hz to 7.5 kHz ± 2 dB (Pressure Response)		

3. Preamplifier 2619

Type	Frequency Range	Dynamic Range (from 5 dB above noise level to max. sinusoidal RMS voltage, 4% distortion)	
4144	3 Hz to 7.5 kHz ± 1.5 dB (Pressure Response)	Linear	
		2 Hz to 200 kHz	48–146 dB
		22.5 Hz to 300 kHz	31–146 dB
		A	17–146 dB
4145	3 Hz to 18 kHz $^{+1.0\ dB}_{-1.5\ dB}$ (Free Field Response)	B	20–146 dB
		C	28–146 dB
4146	1.0 Hz to 7.5 kHz ± 1.5 dB (Pressure Response)		

4. Cathode Follower Type 2615

Type	Frequency Range	Dynamic Range (from 5 dB above noise level to max. sinusoidal RMS voltage, 4% distortion)	
4144	10 Hz to 7.5 kHz ± 1.5 dB (Pressure Response)	Linear	
		2 Hz – 200 kHz	46–146 dB
		20 Hz – 20 kHz	34–146 dB
4145	10 Hz to 18 kHz ± 1.5 dB (Free Field Response)	A	22–146 dB
		B	25–146 dB
		C	32–146 dB

5. Cathode Follower Type 2617

Type	Frequency Range	Dynamic Range (from 5 dB above noise level to max. sinusoidal RMS voltage, 4% distortion)	
4144/46	4.5 Hz to 7.5 kHz ± 1.5 dB (Pressure Response)	20 Hz – 200 kHz	31–146 dB
4145	4.5 Hz to 18 kHz ± 1.5 dB (Free Field Response)		

6. Microphone Carrier System Type 2631

Type	Frequency Range	Dynamic Range (from 5 dB above noise to max. sinusoidal RMS voltage, 4% distortion)	
4144	2 Hz to 7.5 kHz ± 3 dB (Pressure Response)	2 Hz – 20 kHz	65–148 dB
4145	2 Hz to 18 kHz ± 3 dB (Free Field Response)		
4146	0.1 Hz to 7.5 kHz ± 3 dB (Pressure Response)	0.01 Hz – 200 kHz	90–148 dB

4. CALIBRATION

4.1. GENERAL

The condenser microphone and associated instrumentation can be calibrated either electrically or acoustically. Every B & K measuring instrument used in conjunction with the 1" microphones has a built in electrical calibration signal referred to a nominal microphone sensitivity of 50 mV per N/m^2. Each microphone has two correction factors relative to this sensitivity, and the complete noise measuring set up can be calibrated using this reference signal and the appropriate correction factors. When the instrumentation and microphones have been out of use or have been subjected to mishandling, it is advisable to calibrate the system acoustically. Six calibration methods are described below.

The methods in Sections 4.2, 4.3 and 4.4 calibrate the whole sound measuring system while the methods of Sections 4.5, 4.6 and 4.7 calibrate only individual microphone sensitivity and frequency response.

4.2. CORRECTION FACTORS

The open circuit sensitivity and the correction factor, K_o, for the microphone alone are given on the calibration chart accompanying each microphone. Using these figures and the characteristics of the rest of the system it is possible to calibrate an entire system without using a sound source of any kind. If a preamplifier is used remember that the correction factor for the microphone and preamplifier together is K not K_o (See Sec.2.2 Correction Factor). For exact instructions on the calibration of units adjusted to the 50 mV per N/m^2 standard microphone sensitivity consult the instruction manual of the device in question.

4.3. PISTONPHONE

The Pistonphone Type 4220 produces a sound pressure level, of 124 dB ± 0.2 dB at 250 Hz, when fitted to a B & K microphone. This enables a direct calibration of the noise measuring instrumentation. Measurements of

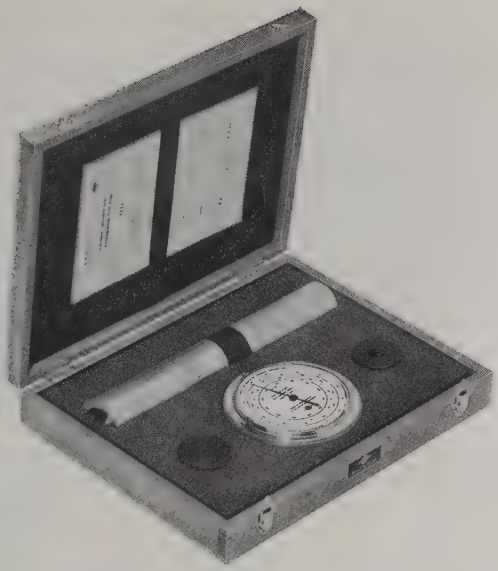


Fig.4.1 Pistonphone Type 4220

high accuracy may be made provided the frequency response and the dynamic linearity (including the attenuators) of the instrumentation following the microphone are known.

The pistonphone (Fig.4.1) is a small, portable, battery operated unit, weighting 0.7 kg (1.54 lbs) and is extremely well suited for field calibration. A barometer is supplied with the instrument for direct reading of ambient pressure corrections, and the adaptors necessary to adjust for different B & K microphones are also supplied. For further information see the Instruction Manual for Type 4220.

4.4. CALIBRATOR TYPE 4230

The B & K Sound Level Calibrator Type 4230 creates a sound pressure level of 94 dB ±0.3 dB at 1 kHz in the coupler volume and is a pocketsize, battery powered unit for field calibration of microphones. (See Fig.4.2). The calibration value obtained for all weighting networks (A, B, C, D and

linear) is the same, as these weighting scales have the same SPL values at 1 kHz. The influence of static pressure is very small, thus the calibration signal is independent of barometric pressure and altitude for ordinary use.

A special construction of the vibrating system makes the equivalent coupler volume more than 200 cm^3 which is greater than the total mechanical volume of the unit (125 cm^3). In practice this means the signal level is independent of the microphone type and the accuracy of the connection to the calibrator.

Fig.4.2 Sound Calibrator Type 4230

4.5. RECIPROCITY CALIBRATION

In the laboratory a high accuracy can be obtained by means of the reciprocity method. This requires very careful measurements and corrections must be made for the cathode follower attenuation ambient pressure, coupler heat-conduction and variations in the equivalent volume of the microphone.

Calibration by means of the Microphone Calibration Apparatus Type 4142 using the reciprocity technique, the method recommended by the American National Standards Institute (S1.10–1966), is relatively time consuming and is useful for the laboratory calibration of microphones only. Two different coupler volumes are available for 1" microphones: 20 and 3 cm^3 usable up to 5 kHz (15 kHz when hydrogen filled). In addition, Type 4142 includes two Electrostatic Actuators (Types UA 0023 and UA 0033) for frequency response calibration of 1" and 1/2" microphones and the necessary 800 V polarization voltage. Finally the Microphone Calibration Apparatus allows the open-circuit voltage sensitivity of the cartridges to be measured.

4.6. ELECTROSTATIC ACTUATOR

The "one-inch" Electrostatic Actuator UA 0023 (Fig.4.3) may be used separately when only the frequency response is to be investigated. The actuator is placed on the microphone cartridge which is held vertically. The actuator has three glass studs which contact the periphery of the cartridge diaphragm. This controls the spacing between the actuator grid and the diaphragm. By applying an AC voltage between the grid and the diaphragm an electrostatic attraction occurs which appears to the diaphragm as a sound pressure. When using a B.F.O. Type 1022 the maximum available voltage of 120 V will provide an equivalent sound pressure level of about 80 dB at twice the oscillator frequency. Variations in the input signal measured in dB result in an equivalent sound pressure variation in dB of twice the input variation. Higher sound levels without frequency doubling may be obtained by using the constant DC bias provided by the 4142.

Since electrostatic pressure is not affected by ambient conditions, the actuator is an excellent method to use in determining the variations in microphone sensitivity under changing environments.

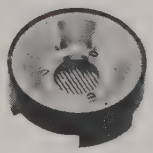


Fig.4.3 Electrostatic Actuator UA 0023

4.7. INSERT VOLTAGE TECHNIQUE

The open-circuit voltage of a microphone at a given single frequency is the voltage which appears at its terminals when the microphone is working into an effectively infinite electrical impedance. This is measured by the substitution method (Insert Voltage Technique). A source of known and adjustable voltage is connected in series with the microphone and an amplifier-indicator system.

Sound pressure and calibrating voltage are applied alternately while the microphone diaphragm is terminated in the same acoustic impedance. The calibrating voltage is then adjusted until it gives the same output as the electromotive force generated by a known sound pressure acting on the

microphone diaphragm in the absence of the calibrating voltage. The open-circuit voltage is equal in magnitude to this calibrating voltage.

This measurement is easily carried out using the Insert Voltage Junction Box Type ZH 0007. The latter can be plugged directly into a Microphone Amplifier Type 2603 or a Spectrometer Type 2112 or any other B & K instrument having a CONDENSER MICROPHONE input.

The Beat Frequency Oscillator Type 1022 may be used as a voltage source.

The measuring procedure is as follows:

1. With the FUNCTION SELECTOR switch of the ZH 0007 in position "Measure" the output voltage from the cathode follower is indicated while the microphone is exposed to a certain known sound pressure.

2. With the sound pressure switched off and the FUNCTION SELECTOR in position "Calibration" adjust the output voltage from the B.F.O. Type 1022 so that the indicated output voltage from the cathode follower is the same as the indicated output in Step 1.

3. The open-circuit voltage is now identical to the output voltage of the B.F.O. (This voltage can be read from the indicating instrument (when calibrated) with the FUNCTION SELECTOR switch in position "BFO Voltage" or from a voltmeter connected to the INSERT RESISTANCE socket of the ZH 0007.

Thus knowing the sound pressure and open circuit voltage the sensitivity of the microphone can be calculated.

The output voltage indicated in Step 2 provides the sensitivity of the microphone loaded with the cathode follower.

The voltage from Step 3 provides the open-circuit sensitivity of the microphone alone.

An extension Cable AO 0027 can be used between the Insert Voltage Junction Box ZH 0007 and the indicating instrument. (If a Microphone Power Supply Type 2801 is employed it is necessary to use the extension cable). It can also be used between the cathode follower plug and the ZH 0007.

5. ACCESSORIES

5.1. RANDOM INCIDENCE CORRECTOR UA 0055

Many noise level measurements involve sound waves impinging on the microphone with variable or undefined incidence angle, e.g. noise from aircraft in flight, noise in workshops, etc. In addition, the spectral composition often varies with angle of incidence. A realistic analysis of the sound pressure is in such cases possible only by means of an omnidirectional linear microphone, i.e. a microphone presenting a sensitivity which is independent both of the incidence angle and the frequency in the measuring range. It has been shown (Fig.2.12) that the sensitivity of the one-inch microphones above 3–4 kHz varies appreciably with angle of incidence. The sensitivity for incidence normal to the microphone is well above the random incidence sensitivity (e.g. 6 dB greater at 10 kHz). This is a source of error when, for example, measuring the sound produced by a machine-tool in a workshop since the reflected sound is attenuated at high frequencies while the direct sound is not.

Fig.5.1 Random Incidence Corrector UA 0055

The one-inch microphone, however, may be made practically omnidirectional up to 10 kHz by using the Random Incidence Corrector UA 0055 (Fig.5.1). This specially shaped device is designed to be mounted in place of the normal protecting grid of the 4145 cartridge and does not significantly affect the normal incidence response. The free-field correction curves of the microphone at incidences other than 0° become practically identical to the normal incidence corrections up to 10 kHz (Fig.5.2). The response at any incidence deviates less than ± 3 dB from the random incidence response up to 10 kHz.

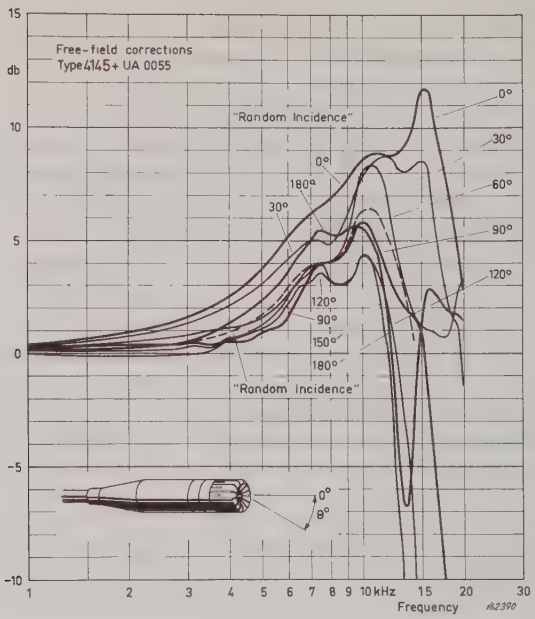


Fig.5.2 Free Field Corrections for 1" Microphone with Random Incidence Corrector UA 0055 (electrostatic actuator method of pressure calibration)

5.2. NOSE CONE UA 0051

The Nose Cone UA 0051 is designed to reduce the noise produced by turbulence when a microphone is exposed to high wind-speeds and fixed directions such as in wind tunnels or ducts.

Fig.5.3 Nose Cone UA 0051

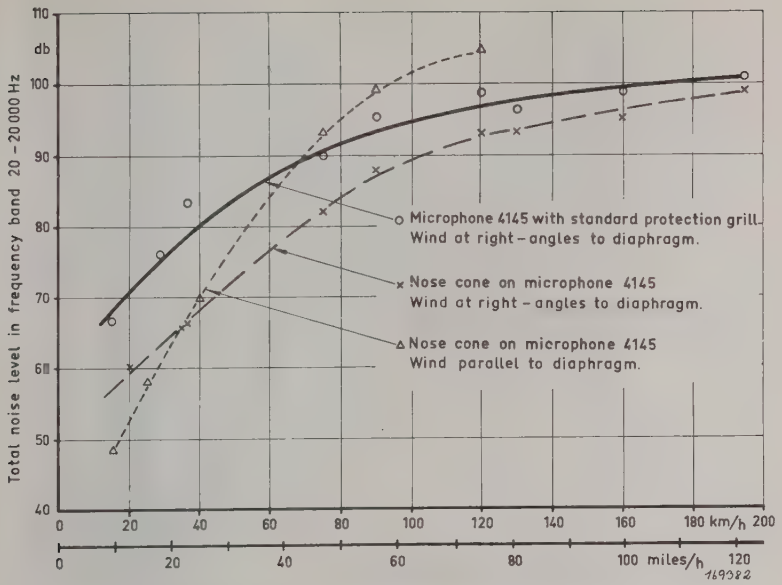


Fig.5.4 Aerodynamically Induced Noise Levels for 1" Microphones

The UA 0051 is made to substitute for the normal protection grid of the microphone and is of a streamlined shape to give the least possible air resistance (Fig.5.3). The fine wire mesh around the circumference allows the sound waves to penetrate to the microphone diaphragm, while a truncated cone behind the mesh reduces the air colume in front of the diaphragm. Typical noise reduction curves for the Nose Cone UA 0051 when fitted to a Condenser Microphone Type 4145 are shown in Fig.5.4. Free field corrections for the 4144/45/46 with UA 0051 are shown in Fig.5.5.

When the Nose Cone is used with the Microphone 4145 excellent omnidirectional characteristics are obtained for the combination, see Fig.5.6.

More information on the design and characteristics of nose cones can be found in B & K Technical Review No. 2, 1960.

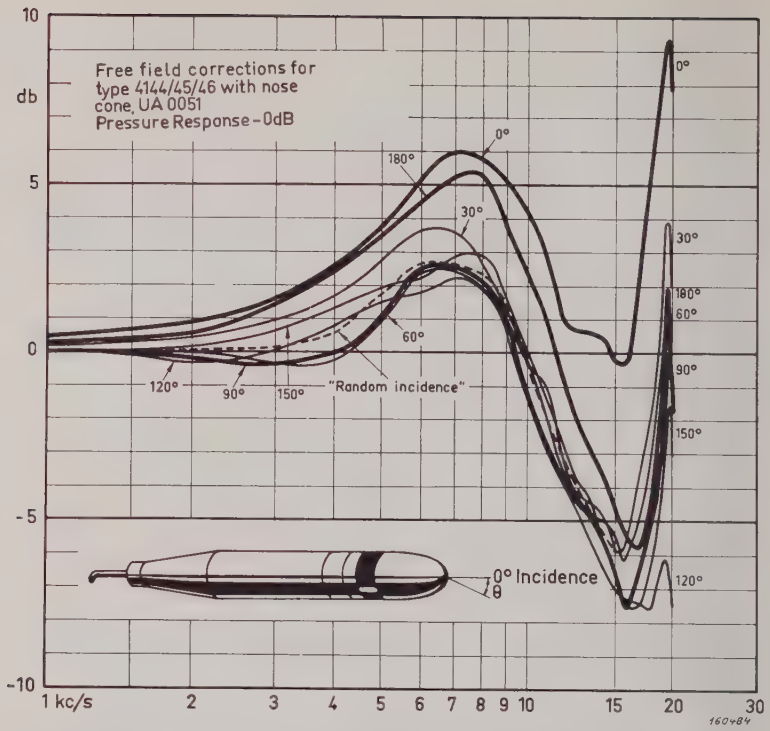


Fig.5.5 Free Field Corrections for Type 4144/45/46 with Nose Cone UA 0051 (electrostatic actuator methos of pressure calibration)

5.3. WINDSCREEN UA 0207 AND UA 0082

When a microphone is exposed to wind, noise will be generated due to the variation of air pressure on the diaphragm. The three principal sources of this are:

I wind velocity variations

II the turbulence created by the microphone when it is placed in the wind

III the interference between the variations in air pressure caused by I and II.

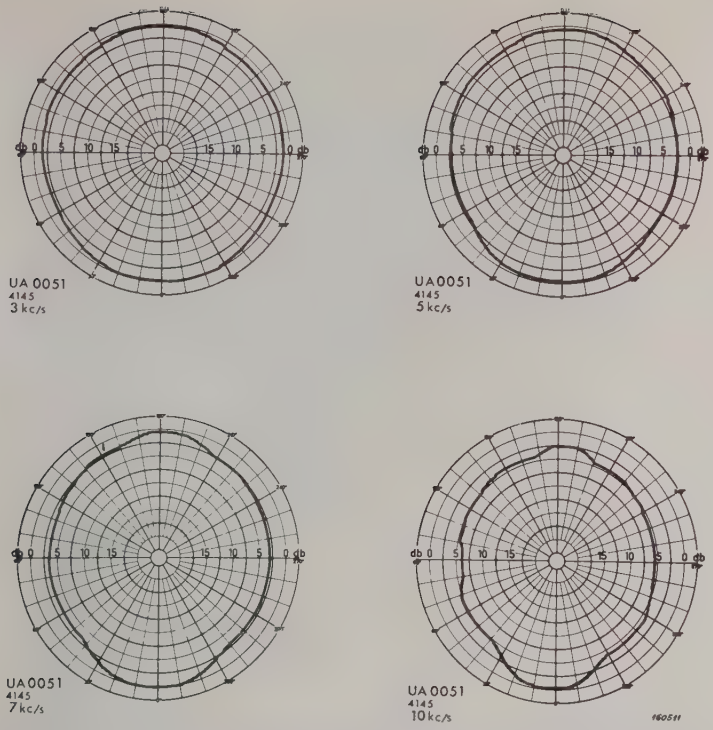


Fig.5.6 Directional Characteristics of the 4145 with Nose Cone UA 0051

Extensive tests have been made with various windscreens and it has been shown that for normal "out of doors" varying wind velocity a spherical windscreen such as the UA 0207 or UA 0082 is best. The material of the

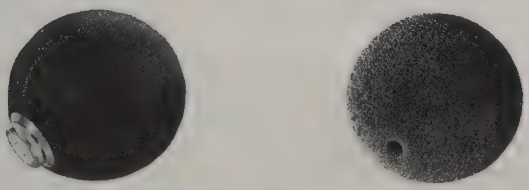


Fig.5.7 Windscreens UA 0082 and UA 0207

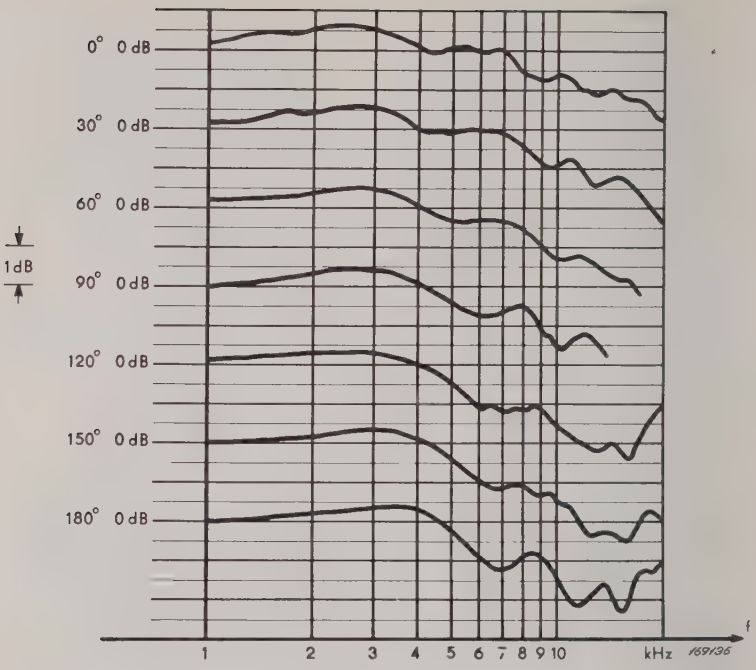


Fig.5.8 Corrections to Free Field Response for Microphone Type 4144/45/46 with Windscreen UA 0207

windscreen presents a great resistance to the wind but the acoustic impedance remains small. The windscreen is of course larger than the microphone so it produces more turbulence, but because the turbulence is farther from the diaphragm the noise is still reduced.

The Windscreen UA 0207 is a ball of specially prepared porous polyurethane sponge. It is best fitted to the microphone when the microphone is attached to the extension rod, then it can be positioned so the diaphragm is at the centre of the windscreen. The windscreen UA 0082 has a nylon cloth covering. It will fit over 1/2" and 1/4" microphones as well as 1" ones and can be used in rain. Free field correction curves for the windscreens are shown in Figs.5.8 and 5.9.

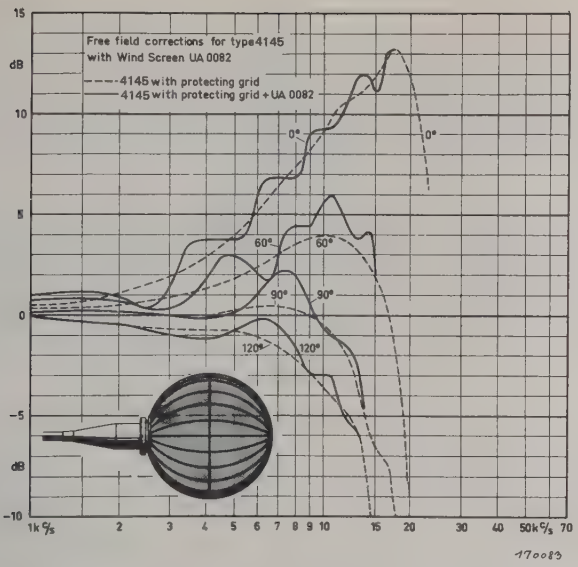


Fig.5.9 Free Field Corrections for Microphone Type 4144/45/46 with Windscreen UA 0082

A description of the design and characteristics of windscreens can be found in B & K Technical Reviews No. 2, 1960 and No. 1, 1966.

5.4. MICROPHONE STAND UA 0049

Microphone Stand UA 0049 fits all types of B & K microphone preamplifiers and is of invaluable assistance in field measurements where the microphone must be placed in an undisturbed region of the sound field, i.e. away from the instruments.

The height of the stand can be adjusted from approximately 50 cm to 140 cm. The Tripod Adaptor UA 0028 (seen on top of UA 0049) may be used separately for adapting the microphones to standard camera tripods with thread 3/8" W.

Fig.5.10 Microphone Stand UA 0049

5.5. EXTENSION CABLES

When it is desired to use the microphones well away from the associated instruments an extension cable must be used after the preamplifier to make the connection. Several standard lengths of extension cables are available for this purpose.

Extension Cable AO 0027 is a 3 m long multi-core shielded cable supplied with B & K microphone connectors in both ends. The diameter is 6 mm. The capacity to ground of the signal conductor is approximately 100 pF/m (33 pF/foot). Each conductor is insulated with polyethylene and the outside of the cable has a grey P.V.C. covering. The cable is specially designed for low leakage between the cores.

Extension Cable AO 0028 is a 10 m long multi-core shielded cable, supplied with a co-axial signal conductor and B & K microphone connectors at both ends. The diameter is 9 mm. The cable is specially designed to give low microphony. Excellent shielding of the signal core and low leakage between the cores enable long runs of cables to be used. The capacity of the co-axial signal conductor to ground is approximately 57 pF/m (19 pF/foot). The conductors are polyethylene insulated and the cable is covered with a grey P.V.C. covering.

Extension Cable AO 0029 is identical to AO 0028, but 30 m long.

Extension Cable AO 0033 may be used for remote mounting of microphones from the 2203 and is 3 meters long.

Tape Extension Cable AR 0001 is a very flexible, flat 7-cored microphone cable used when sound insulation and reverberation measurements are made in buildings where it is necessary to carry a microphone cable through closed windows and doors. The flat cable can easily follow sharp bends, having a thickness of only 0.2 mm. Cable length is about 30 cm (1 ft).

Flexible Extension Rod UA 0039 introduces a flexible goose-neck between the preamplifier and the microphone. It is designed for use with ambient temperatures up to 150°C, and it accepts both the one-inch and the half-inch microphones on the input end. It extends the "Guard ring" system of the preamplifier. Total length: 46 cm (11/2 ft).

5.6. ACOUSTIC COUPLERS

Various couplers are in serial production in connection with the B & K Artificial Ear and Microphone Calibration Apparatus and are in accordance with the ANSI and IEC Standards. The following couplers are designed for use with the Microphone Types 4144 and 4146 (the nominal volumes include the nominal equivalent volume of the cartridge, i.e. 0.15 cm^3).

The Acoustic Coupler Type DB 0138 is a coupler of 2 cm^3 for measurements on insert type earphones and fulfils the ANSI and IEC Standards. It is included as a standard fitting to the Artificial Ear Type 4153. **The DB 0160** is a 6 cm^3 coupler for acoustical measurements on earphones and fulfils the requirements for the NBS Type 9A-Coupler. The DB 0160 includes: 1 NBS coupler, 1 Coupler Adaptor DB 0111, and 1 stop collar for mounting the coupler on the one-inch microphones. **The Coupler DB 0161** is a 6 cm^3 coupler similar to DB 0160 but designed to fulfil the requirements of the ANSI S1.10–1966 for Type 1 couplers. It is mounted in the same manner as the DB 0160.

Further information about the couplers will be found in the B & K Technical Review No. 4, 1961.

Note: If no special precautions are taken the gas contained in the coupler also fills the microphone cartridge. If the gas density differs markedly from that of air at atmospheric pressure, a change in damping and in frequency response is to be expected.

6. SPECIFICATIONS

6.1. TYPE 4144

Dimensions:

Diameter: 23.77 mm ± 0.05 mm
Height:
Without protecting grid:
17.0 mm $^{+0.0}_{-0.1}$ mm
With protecting grid:
19.0 mm

Coupler/Grid Mounting Thread: 23.11–60 NS 2

Polarization Voltage: 200 V

Sensitivity:
(Reference 250 Hz) −26 dB ± 1.5 dB re 1 V per N/m^2

Frequency Response:
(Calibration point 250 Hz)

2 Hz to 4 Hz	$^{-1.0}_{-3.0}$ dB
4 Hz to 8 Hz	$^{+0.0}_{-1.0}$ dB
8 Hz to 250 Hz	$^{+0.0}_{-0.5}$ dB
250 Hz to 2.5 kHz	$^{+0.5}_{-0.0}$ dB
2.5 kHz to 3.5 kHz	$^{+1.0}_{-0.0}$ dB
3.5 kHz to 7.5 kHz	± 1.5 dB

Resonant Frequency:
(90° phase shift) 8 kHz

Dynamic Range:
(Ref. 2 x 10^{-5} N/m^2)

Upper Limit (4% distortion) 144 dB
Lower Limit determined by noise level of preamplifier
Safety Limit 160 dB.

Capacitance:	55 pF
Stability:	at 150°C approx. 0.2 dB/hour at room temp. approx. 0.2 dB/1000 years (extrapolated)
Temperature Coefficient:	Less than ± 0.008 dB/°C
Equivalent Volume:	0.15 cm^3
Ambient Pressure: (Reference 250 Hz)	0.3 dB increase for 100 mm Hg decrease
Pressure Equalizing Time Constant:	Between 0.08 and 0.16 sec.
Electrical Time Constant: (after 24 Hours in 85% rel. humidity)	More than 120 sec.
Magnetic: (worst direction)	100 A/m < 18 dB SPL
Vibration: (axial direction)	1 g ≃ 88 dB SPL
Accessories Included:	Silica Gel Cap UA 0135

6.2. TYPE 4145

Dimensions:	Diameter: 23.77 mm ± 0.05 mm Height: Without protecting grid: 17.0 mm $^{+0.0}_{-0.15}$ mm With protecting grid: 19.0 mm
Coupler/Grid Mounting Thread:	23.11–60 NS 2
Polarization Voltage:	200 V
Sensitivity: (Reference 250 Hz)	−26 dB ± 1.5 dB re 1 V per N/m^2
Frequency Response: (Calibration point 250 Hz)	2 Hz to 4 Hz $^{-1.0}_{-3.0}$ dB 4 Hz to 8 Hz $^{+0.0}_{-1.0}$ dB 8 Hz to 250 Hz $^{+0.0}_{-0.5}$ dB 250 Hz to 4 kHz ± 0.5 dB 4 kHz to 12.5 kHz ± 1.0 dB 12.5 kHz to 18 kHz $^{+1.0}_{-1.5}$ dB
Resonant Frequency: (90° phase shift)	9 kHz
Dynamic Range: (Ref. 2×10^{-5} N/m^2)	Upper Limit (4% distortion) 144 dB Lower Limit determined by noise level of preamplifier Safety Limit 160 dB
Capacitance:	66 pF
Stability:	at 150°C approx. 0.2 dB/hour at room temp. approx. 0.2 dB/1000 years (extrapolated)

Temperature Coefficient:	Less than ± 0.006 dB/°C
Equivalent Volume:	0.13 cm^3
Ambient Pressure:	0.3 dB increase for 100 mm Hg decrease
Pressure Equalizing Time Constant:	Between 0.08 and 0.16 sec.
Electrical Time Constant: (After 24 Hours in 85% rel. humidity)	More than 120 sec.
Magnetic: (worst direction)	100 A/m $<$ 18 dB SPL
Vibration: (axial direction)	1 g $\simeq$ 88 dB SPL
Accessories Included:	Silica Gel Cap UA 0135

6.3. TYPE 4146

Dimensions:	Diameter: 23.77 mm ± 0.05 mm Height: Without protecting grid: 17.0 mm $^{+0.0}_{-0.1}$ mm With protecting grid: 19.0 mm
Coupler/Grid Mounting Thread:	23.11–60 NS 2
Polarization Voltage:	200 V
Sensitivity: (Reference 250 Hz)	-26 dB ± 1.5 dB re 1 V per N/m^2
Frequency Response: (Calibration point 250 Hz)	0.1 Hz to 0.2 Hz $^{+0.0}_{-3.0}$ dB 0.2 Hz to 0.4 Hz $^{+0.0}_{-1.0}$ dB 0.4 Hz to 250 Hz $^{+0.0}_{-0.5}$ dB 250 Hz to 2.5 kHz $^{+0.5}_{-0.0}$ dB 2.5 kHz to 3.5 kHz $^{+1.0}_{-0.0}$ dB 3.5 kHz to 7.5 kHz ± 1.5 dB
Resonant Frequency: (90°C phase shift)	8 kHz
Dynamic Range:	Upper Limit (4% distortion) 144 dB Lower Limit determined by noise level of preamplifier Safety Limit 160 dB
Capacitance:	55 pF
Stability:	at 150°C approx. 0.2 dB/hour at room temp. approx. 0.2 dB/1000 years (extrapolated)

Temperature Coefficient:	Less than ± 0.008 dB/°C
Equivalent Volume:	0.15 cm^3
Ambient Pressure:	0.3 dB increase for 100 mm Hg decrease
Pressure Equalizing Time Constant:	More than 1.6 sec.
Electrical Time Constant: (After 24 Hours in 85% rel. humidity)	More than 120 sec.
Magnetic: (worst direction)	100 A/m $<$ 18 dB SPL
Vibration: (axial direction)	1 g $\simeq$ 88 dB SPL
Without Polarization: The capacitance, C, becomes while the SPL changes C by an amount ΔC	46 pF $\Delta C = 10^{-2}$ pF per N/m^2 (or $\frac{\Delta C}{C} = 2.2 \times 10^{-4}$ m^2/N)

The Resultant Frequency Response is:

(Calibration point 250 Hz)	0.1 Hz to 0.2 Hz	$^{+0.0}_{-3.0}$ dB
	0.2 Hz to 0.4 Hz	$^{+0.0}_{-1.0}$ dB
	0.4 Hz to 250 Hz	$^{+0.0}_{-0.5}$ dB
	250 Hz to 2 kHz	$^{+0.5}_{-0.0}$ dB
	2 kHz to 3 kHz	$^{+1.0}_{-0.0}$ dB
	3 kHz to 8.5 kHz	± 2.5 dB

Accessories Included: Case UA 0240 Containing Silica Gel

B & K INSTRUMENTS:

ACOUSTICAL....
Condenser Microphones
Piezo-Electric Microphones
Microphone Preamplifiers
Microphone Calibration Equip.
Sound Level Meters
(general purpose-precision- and impulse)
Standing Wave Apparatus
Tapping Machines
Noise Limit Indicators

ELECTROACOUSTICAL....
Artificial Ears
Artificial Mouths
Artificial Mastoids
Hearing Aid Test Boxes
Telephone Measuring Equipment
Audiometer Calibrators
Audio Reproduction Test Equip.

STRAIN....
Strain Gauge Apparatus
Multipoint Panels
Automatic Selectors
Balancing Units

VIBRATION....
Accelerometers
Accelerometer Preamplifiers
Accelerometer Calibrators
Vibration Meters
Magnetic Transducers
Capacitive Transducers
Vibration Exciter Controls
Vibration Programmers
Vibration Signal Selectors
Mini-Shakers
Complex Modulus Apparatus
Stroboscopes

GENERATING....
Beat Frequency Oscillators
Random Noise Generators
Sine-Random Generators

MEASURING....
Measuring Amplifiers
Voltmeters
Deviation Bridges
Megohmmeters

ANALYZING....
Band-Pass Filter Sets
Frequency Spectrometers
Frequency Analyzers
Real-Time Analyzers
Slave Filters
Psophometer Filters
Statistical Analyzers

RECORDING....
Level Recorders
(strip-chart and polar)
Frequency Response Tracers
Tape Recorders

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